

MODERN AGRICULTURAL MATHEMATICS

1. The first part of the document is a list of names and addresses of the members of the committee.

MODERN AGRICULTURAL MATHEMATICS

*A Textbook for Students of Agriculture in High Schools,
Vocational Schools, and Rural Schools; and a Handy Refer-
ence Book for Farmers and Other Workers in the Various
Branches of Agriculture, Containing Methods of Calculation
for All Types of Agricultural Problems*

By

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ILLUSTRATED



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PREFACE

THE use of mathematics is essential in many farm activities. This book contains selected portions of the broad field of mathematical knowledge sufficient, in the opinion of the author, for the needs of the agricultural student and worker. The text is appropriate for those who have already learned the fundamental operations of computation, namely, addition, subtraction, multiplication and division of whole numbers, fractions and decimals, as taught in the standard program of arithmetic in elementary schools. One school year should be spent for the completion of this course in agricultural mathematics. The book is divided into two parts, each of which is intended for one half-year of study.

In general, three aims are fostered. First, it is desired to impart an understanding of the development and structure of the subject of mathematics. Second, the student is trained in the analysis of problems, and in the application of mathematical processes to their solution. Third, the book teaches the methods of solution of all types of mathematical problems arising in connection with the many branches of agriculture.

Part I of the book seeks to develop by logical steps the various rules and formulas used in the measurement of length, direction, area, volume, and also specific relationships between different units of measure. In the course of this procedure, the student will become acquainted with some algebra, geometry and trigonometry. However, material is avoided that may be too difficult for a student whose entire mathematical background consists of rudimentary arithmetic. The author has also kept in full view throughout the text the applications to agriculture. Each small unit of mathematics presented is followed by a series of farm problems. Certain applications have been given special attention, as for example, Crops and Or-

chards, and the Measurement of Lumber and Timber, which have been treated as separate topics.

Scientific methods are imperative for success in modern farming. Moreover, a reasonable financial return is dependent upon competent business practices. Expert computation is an important aid in both of these aspects of farm management. The detailed consideration of dairying, the feeding of farm animals, soil fertility, fertilizers, farm mechanics, and finance and management, in Part II of the text, provides the necessary skills in calculation. Despite the wide selection of examples, the farmer may sometimes be confronted with problems not included in this book. The author expects that the readers will have acquired sufficient power in mathematics to be able to solve such new types of examples that may arise in their work.

Arithmetic drills, reference tables and answers to problems, are contained in the appendix. The body of the book includes sample solutions of problems, projects in measurement, and lists of references. The author is hopeful that the entire text will be of great assistance to the many people training for or now engaged in agricultural pursuits.

Credit is due the late Principal James D. Dillingham and Principal Alfred S. Roberts, and their associates, who have nurtured the Agricultural Division of Newtown High School, under the auspices of the Board of Education of the City of New York. It is in this school that the author has experimented with the course of Farm Mathematics, finally culminating in the subject matter included in this book.

The author is indebted to Clara C. Eaton, Head of the Mathematics Department of Newtown High School, for her many valuable suggestions; and to Clinton E. Skifstad, Teacher-in-charge, Robert P. Armstrong, William A. Morgan and C. Laurin March, of the Agricultural Department, for their helpful contributions.

Grateful appreciation is acknowledged to the United States Department of Agriculture and to the State Agricultural Experiment Stations cited in this book, and members of the staffs, for their information, illustrations, and tables.

PREFACE

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Indebtedness is acknowledged to the Portland Cement Association, for the use of the illustrations reproduced on pages 74, 197, 228, 229 and 230; to the Lafayette Instruments Company for those on pages 7, 10, and 17; to the De Laval Separator Company, for the illustration on page 141; to the Holstein Friesian Association of America, for the illustration on page 136; to the American Jersey Cattle Club, for the illustration on page 139; and to the various other sources of illustrations acknowledged in this book.

The author expresses his deep appreciation to Florence E. Nadler, for her invaluable aid in the preparation of the manuscript and in the proofreading.

MAURICE NADLER.

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MODERN AGRICULTURAL MATHEMATICS

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Chapter I

MEASUREMENT OF LENGTH

WHEN you are planning the agricultural activities for the year, you must consider various measurements about the farm, as, for example, lengths and widths of fields, roads and buildings. This need for measuring can be traced back thousands of years, for agriculture is one of the oldest occupations of man.

Early Egyptians made use of a unit of measurement called the Cubit, which was the length of the forearm, from fingertip to elbow. This is about 20 inches long, but varies, of course, for different people. Another unit, the Digit, was the breadth of a finger, about $\frac{3}{4}$ of an inch. Years later, King Henry I decreed that the lawful yard was the distance from the tip of his nose to the end of the thumb of his outstretched arm. Many other units, not mentioned here, were used by Greeks, Romans and other nations.

Measurement to-day is more scientific. The lengths of the modern units are fixed by comparing with metal bars kept in government vaults. In European countries, and also for certain purposes in America, the metric system is used. Thus, a field may be 50 meters long, and the length of an ear of corn may measure 20 centimeters. The system that we apply is shown in the following table.

Linear Measure

$$12 \text{ inches} = 1 \text{ foot (ft.)}$$

$$5\frac{1}{2} \text{ yards} = 1 \text{ rod (rd.)}$$

$$3 \text{ feet} = 1 \text{ yard (yd.)}$$

$$320 \text{ rods} = 1 \text{ mile (mi.)}$$

As each yard equals 3 feet, one rod equals $5\frac{1}{2}$ times 3, or

$$1 \text{ rod} = 16\frac{1}{2} \text{ (16.5) feet}$$

Then one mile equals 320 times 16.5, or

$$1 \text{ mile} = 5280 \text{ feet}$$

There are practical reasons for having different units in the same system. While the inch may be suitable for recording the thickness of a concrete wall, the distance between two villages requires the more convenient "mile." The selection of the most appropriate unit is a matter of your own good judgment.

It may be necessary to compare two lengths that have been measured in different units, or to add or subtract such lengths. You must therefore learn how to change from one unit to another. This is called **conversion**, and the numbers in the table used for this purpose are called **conversion factors**. For example, the number 3 is used to change yards to feet, and thus 3 is a conversion factor.

PRACTICE IN CONVERSION OF MEASUREMENTS OF LENGTHS

1. Memorize all the conversion factors of linear measure found near the bottom of page 1.

2. **SAMPLE METHOD** for converting to lower denominations.

Change a length of 7 rd. 5 yd. 2 ft. to inches (in.).

7 rd.: $7 \times 16\frac{1}{2} = 115\frac{1}{2}$ ft.	Add:	
$115\frac{1}{2} \times 12 = 1386$ in.		7 rd. = 1386 in.
5 yd.: $5 \times 3 = 15$ ft.		5 yd. = 180 in.
$15 \times 12 = 180$ in.		2 ft. = 24 in.
2 ft.: $2 \times 12 = 24$ in.	<i>Answer</i>	1590 in.

RULE 1. To change from a unit of higher denomination to a unit of lower denomination, multiply by the conversion factor.

3. Change 19 yd. to inches. (How many inches to the yard?)
4. Change 5 mi. to feet; change this answer to inches.
5. Change 18 rd. to yards; then to feet, to inches.
6. Change 7 mi. to rods; this answer to feet.
7. Change the measurement 8 rd. 4 yd. to feet.
8. Change the measurement 13 rd. 3 yd. to inches.

9. SAMPLE METHOD for converting to higher denominations.

Change 1615 in. to higher denominations.

$1615 \div 12 = 134$ ft. and a remainder of 7 inches.

$134 \div 16\frac{1}{2} :$ The quotient is 8 rods (or 132 ft.).

Subtract: 134 ft.

Answer:

132 ft.

8 rd. 2 ft. 7 in.

2 ft. remainder

Prove this answer by changing back to inches.

RULE 2. To change from a unit of lower denomination to a unit of higher denomination, divide by the conversion factor.

10. How many feet are there in 756 inches; how many yd.?

11. How many yards are there in 216 inches; in 7272 in.?

12. Find the number of miles in 58,080 ft.; in 8320 rods.

13. Find the number of rods in 363 feet.*

14. Find the number of rods in 462 yards.

15. Find the number of rods in 561 ft.; in 528 yards.

16. Change to higher denominations:

(a) 1987 inches.

(c) 13,885 inches.

(b) 83 feet.

(d) 310 feet.

Expressing a lower denomination as a fraction of a higher denomination.

Illustrations:

(a) 2 inches = $\frac{2}{12}$ or $\frac{1}{6}$ of a foot.

(b) 1 foot = $\frac{1}{3}$ of a yard.

* Although you may understand perfectly the correct method in these examples and other examples on pages 2 and 3, incorrect arithmetic will cause wrong answers. If this is your difficulty now, and at any other place further on in the book, you should turn to pages 269 to 276, in the back of the book, for Special Drill. These Special Drills are reviews in the mechanical arithmetic needed for agricultural problems. The exercises are arranged according to separate topics, such as fractions, decimals, etc.

At this time, you are advised to work out Special Drills numbers 3, and 7, on pages 270 and 272.

- (c) 40 rods = $4\frac{9}{320}$ or $\frac{1}{8}$ of a mile.
 (d) 440 feet = $4\frac{10}{280}$ or $\frac{1}{12}$ of a mile.
17. Express as fractions of a foot:
 (a) 1 in.; 3 in.; 5 in.; 7 in.; 9 in.; 11 in.;
 (b) 4 in.; 6 in.; 8 in.; 10 in.
18. Express as fractions of a mile: 80 rd.; 1760 ft.
 19. Express as fractions of a mile: 440 yd.; 20 rd.
 20. How many yards are there in 848 feet?
 Note: The remainder may be written as a fraction of the divisor, thus, the remainder two, in this example, means $\frac{2}{3}$ of a yard.
21. Find the number of feet in 904 in.; in 329 inches.
 22. Find the number of yards in 1735 ft.; in 2059 feet.

Problems in Planting.

1. When corn is planted in rows 3 ft. 8 in. apart, how many rows are in a field that measures 220 feet across?

Suggestion: Change both measurements to the same unit (in this case, to inches), and then you may divide these two numbers having the same unit.

2. Plan the number of rows of corn across a field 341 ft. wide, when the rows are placed 44 inches apart.
 3. If drills of potatoes are 3 feet apart, how many drills are there in a field measuring 12 rods across?
 4. What is the width of a field, in feet, needed for 88 rows of cotton, planted 2 ft. 6 in. apart?

Suggestion: Change the inches to a fraction of a foot, and then you can multiply more easily.

5. How many yards long should a field be, in order to plant 91 Christmas trees 4 feet apart in each row?
 6. How many tobacco plants, placed 20 in. apart in the row, are there in a row, the length of a 250-foot field?
 7. How many rows of beans can be planted in a 100-foot field, when the rows are placed 2 ft. 6 in. apart? /

The spacing of rows, and of the seeds and plants along the row, may vary in different localities, even for the same crop,

because of the type of soil, and other local conditions. By communicating with the nearest Agricultural Station, the farmer will be able to obtain the most recent results of experiments in the spacing of seeds and plants. The data in the table below gives varying ranges of spacing for typical crops.

USUAL SPACING OF ROWS FOR CERTAIN CROPS

<i>Crop planted</i>	<i>Distance between rows</i>
Corn	44 inches
Cotton	2½ to 5 feet
Potato	3 to 3½ feet
Sugar Beet	20 to 28 inches
Sugar Cane	4 to 6 feet
Tobacco Plants	3 to 4 feet

Problems in Fence Building.

1. Find the length of fencing needed for three sides of a field, which measure $161\frac{1}{2}$ ft., $148\frac{1}{4}$ ft. and $163\frac{1}{2}$ ft., respectively.*
2. How much fencing is needed to enclose a field that measures 190 ft., $212\frac{3}{4}$ ft., 190 ft. and $212\frac{3}{4}$ ft. on each of the four sides, respectively?
3. When fence posts are set one rod apart, how many are needed for 2970 feet of fencing?
4. A farmer wishes to build a fence around a square farm, a total distance of 640 rods. How many posts will he use, when he places them $16\frac{1}{2}$ feet apart?

Problems in Construction.

5. Concrete sidewalks are built in sections about 5 ft. long. How many such sections are needed for a walk which is 35 yards long?
6. When drain tile is placed at intervals of 40 feet, how many lines will be constructed across an 80-rod field?

* 7. Work out Special Drill number 1 on page 269, in addition of fractions.

8. Plan the number of lines of drain tile placed 25 feet apart, across a field 150 yards wide.

General Problems in Linear Measure.

9. How much baseboard is needed for a room, if its width at each end is 14 ft. 7 in., and its length on each side measures 27 ft., 9 in.?

Sample Addition

of
Mixed Units.

Solution of Problem 9:

14 ft. 7 in.	(1) Add the inches.
14 ft. 7 in.	(2) 32 in. = 2 ft. 8 in.
22 ft. 9 in.	(3) Add the 2 ft. to the
22 ft. 9 in.	column of feet.

Answer 74 ft. 8 in.

10. If 33 in. are cut from a wire 4 yd. 1 ft. 10 in. long, what is the length of the remaining piece?

Sample
Subtraction
of

Mixed Units.

Solution of Problem 10:

3	4	(1) 33 in. = 2 ft. 9 in.
4 yd. 1 ft. 10 in.		(2) Subtract inches
2 ft. 9 in.		(3) Borrow 1 yd.
3 yd. 2 ft. 1 in.		(4) Subtract ft.

Answer

Add:

11. 14 ft. 10 in.
29 ft. 8 in.
16 ft. 9 in.
38 ft. 2 in.

12. 3 yd. 2 ft. 6 in.
6 yd. 1 ft. 7 in.
19 yd. 2 ft. 4 in.
25 yd. 2 ft. 5 in.

Subtract:

13. 10 ft. 3 in.
4 ft. 7 in.

14. 15 yd. 1 ft. 8 in.
4 yd. 2 ft. 9 in.

15. Solve problem 11 by changing the in. to fractions of a foot and by adding the mixed numbers.

16. Solve problem 13 by changing the in. to fractions of a foot and by subtracting the mixed numbers.*

* 17. Work out Special Drill number 2 on page 270, in subtraction of fractions.

Actual Measurement of Lengths.

Your equipment for the measurement of length should be: a twelve-inch ruler with metal edging, and a 100-foot steel tape. For markers, when you are measuring a greater length than 100 feet, round wooden or steel stakes, about 18 inches long, are suitable. You can make these from material about 1 inch in diameter, and cut down one end to a point. For a high degree of accuracy in very small measurements, such as needed for machinery, the Vernier Caliper and the Micrometer are important instruments.

**The Accuracy of Measurement.**

How accurately can you measure? Try this experiment. Measure the length of a room with the steel tape. Let three or four other people make the same measurement. Do all of you get exactly the same result? Measure the same distance yourself several times. Do you get the same result all the time?

The result of measurement is never exact! Finding the length of this page means seeing how many times you can fit the unit (an inch) into the length. Using a ruler does this automatically. The manner in which you place the instrument, the grade of the instrument, your eyesight, and even other conditions, cause variations in the result. The surveyor, who is an expert, does not get a perfect result. Only those numbers which are obtained by counting can be perfect. For example, that there are 12 cows in a barn at a certain moment cannot be disputed.

Therefore, measure as carefully as possible, but always **round off** to your particular needs. Your steel tape is usually subdivided into tenths and hundredths of a foot. If you want the length of a field for planting purposes, then finding that distance in feet is sufficiently accurate. However, you may want to measure the length of a stalk of corn. This, you would want in inches, but not necessarily fractions of an inch.

As your instrument may give you a higher degree of accuracy than you may require, use the following rules for rounding off.

RULE 3. Approximation: Read the instrument one degree of accuracy more than required, and then

- (a) Increase the answer by 1 if the extra place is $\frac{1}{2}$ or more, or
- (b) Drop the extra place if it is less than $\frac{1}{2}$.

Method of Using the Rule of Approximation.

- (1). Suppose you wish to measure to the nearest foot.
 - (a). If the steel tape reads 92.8 feet, then the length, to the nearest foot, is 93 ft. (.8 would be exactly $\frac{1}{2}$ of a foot. Thus, .8 increases 92 to 93 feet.)
 - (b). If the tape reads 76.3 feet, then the length, to the nearest foot, is 76 ft.
 - (c). If the tape is subdivided into inches instead of tenths, and the reading is 84 ft. 6 in., then the length, to the nearest foot, is 85 ft. (Six inches is $\frac{1}{2}$ of a foot.)
 - (d). If this tape reads 59 ft. 4 in., then the length, to the nearest foot, is 59 feet.
- (2). Suppose you wish to measure to the nearest inch.
 - (a). If the ruler reads $8\frac{1}{2}$ in., then the length, to the nearest inch, is 9 inches.
 - (b). If the ruler reads $6\frac{3}{4}$ in., then the length, to the nearest inch, is 7 inches.
 - (c). If the ruler reads $5\frac{1}{4}$ in., then the length, to the nearest inch, is 5 inches.
 - (d). Some rulers are subdivided into tenths of an inch. In such case, apply part (a) of Rule 3. for .5 and over, and use part (b) of the Rule for .4 and less.

Practice in Rounding Off.

1. Express the following linear measurements "to the nearest foot."

- | | |
|-----------------|------------------|
| (a) 48.2 feet. | (d) 147.5 feet. |
| (b) 157.8 feet. | (e) 257.0 feet. |
| (c) 169.9 feet. | (f) 88 ft. 4 in. |

- | | |
|-------------------|--------------------|
| (g) 164 ft. 5 in. | (i) 71 ft. 6 in. |
| (h) 214 ft. 9 in. | (j) 199 ft. 11 in. |

2. Express the following linear measurements "to the nearest inch":

- | | |
|------------------------------|------------------|
| (a) $9\frac{1}{8}$ inches. | (f) 16.7 inches. |
| (b) $15\frac{3}{16}$ inches. | (g) 21.3 inches. |
| (c) $25\frac{7}{8}$ inches. | (h) 12.5 inches. |
| (d) $29\frac{1}{2}$ inches. | (i) 6.7 inches. |
| (e) $14\frac{3}{8}$ inches. | (j) 19.1 inches. |

Projects in Actual Measurement.

1. Estimate the length and width of a room. Then measure these dimensions "to the nearest foot." How accurate is your judgment?

2. Estimate the distance between two trees or two rocks. Then measure the distance "to the nearest foot," and compare with your estimate.

3. Estimate the length and width of a field (use more than 100 feet). Then measure these dimensions "to the nearest foot" with the steel tape and stakes. Is your judgment in recognizing distances improving?

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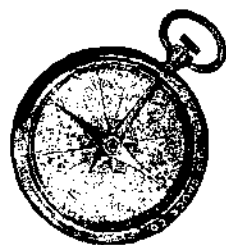
Chapter II

MEASUREMENT OF DIRECTION

WHEN you draw a plan of a farm on paper, you must know the **directions**, as well as the linear measurements of the lengths and widths of the fields, roads and buildings. Man was measuring directions probably even before he began measuring lengths.

Ancient Egyptians surveyed their lands with simple instruments which gave modern man ideas for some of the present high grade measuring instruments. The Romans drew maps, and drafted plans for buildings, roads and bridges. Measurement of direction was used by the Greeks in their work in Astronomy and Navigation. We are amazed by the extent of knowledge of mathematics displayed by early civilization in constructions, such as sewers, canals, roads, buildings, and other structures.

When you measure a length, you are following the distance from the **initial point** of a line (the beginning) to the **terminal point** (the end). Similarly, direction is measured by following the **turning** (revolution) from the **initial line** to the **terminal line** while this turning is performed about a fixed point (the vertex). A compass, pictured on the left, measures direction by showing the amount of revolution from the magnetic North Pole.



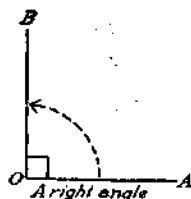
Compass

In using a compass, the **initial line** is the line pointing to the magnetic North Pole, the vertex is the pivoting point of the compass needle, and the **terminal line** is the direction in which the needle is pointing. However, we use other initial lines besides the magnetic North Pole, in measuring direction.

Direction by Angles.

An angle is the amount of turning from an initial line to the terminal line. This initial line can be in any desired position, although it is often customary to draw the line on paper horizontally. The standard direction of rotation is counter-clockwise (opposite the direction in which the hands of a clock move).

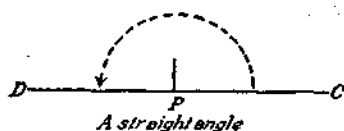
1. In the diagram at the right, the initial line is indicated by the letters O and A at its ends, and is read line OA. If line OA is turned through one complete revolution, it will be returned to its original position. When line OA is turned through $\frac{1}{4}$ of a complete revolution, it will reach the position of line OB, the terminal line, and the angle formed is called a **right angle**. We read this angle as Angle AOB or angle BOA (the vertex must be the center letter).



2. An angle less than a right angle, that is, caused by less turning than a one-quarter revolution of the initial line, is called an **acute angle**. The acute angle at the left can be read as angle a, another method for identifying an angle.



3. An angle formed by a one-half revolution of the initial line is called a **straight angle**, because the terminal line falls along the same line as the initial line (but in the opposite direction). Angle DPC (or angle CPD), at the right, is a straight angle. The initial line PC has been turned about the vertex P, and the terminal line is line PD.



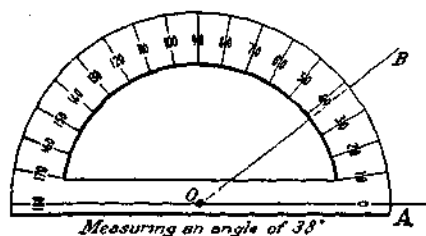
4. An **obtuse angle** is formed by more than one-quarter and less than one-half of a complete revolution. This makes an obtuse angle less than a straight angle and more than right angle. Obtuse angle m is larger than angle AOB and smaller than angle CPD.



Measurement of Angles by Degrees.

The unit of angle measurement is an angle of **one degree** (written 1°), which is $\frac{1}{360}$ th part of a complete revolution. There are exactly 360 degrees in one revolution. Therefore a right angle contains 90° ($\frac{1}{4}$ of $360 = 90$); and a straight angle contains 180° ($\frac{1}{2}$ of $360 = 180$).

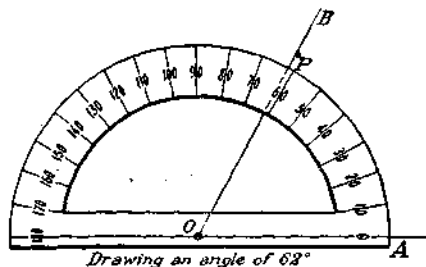
An instrument for the measurement of the number of degrees in an angle is the **protractor**. The protractor represents the straight angle divided into 180 equal degrees.



A. We use the protractor by fitting the right half of the lower edge (at 0°) on the initial line of the angle, with the center point directly over the vertex of the angle. The reading where the terminal line of the angle

crosses under the protractor is the number of degrees in the angle. See the diagram above.

B. A protractor can be used for drawing an angle of a required number of degrees. Draw an initial line, and then place the protractor just as in A. Mark a dot outside of the protractor at the reading of the required number of degrees. Remove the protractor and complete the angle by drawing the terminal line.



Practice in Angle Measurement.

1. Express in degrees $\frac{1}{8}$, $\frac{1}{6}$, $\frac{1}{4}$, $\frac{1}{2}$, $\frac{2}{3}$, $\frac{1}{12}$, and $\frac{1}{16}$ of a complete revolution.
2. Draw angles of 35° , 69° , 107° , 164° , 90° , and 180° .
3. Draw an acute angle; an obtuse angle. Measure each angle with the protractor. Name each angle by 3 letters.

Some Mechanical Drawing.

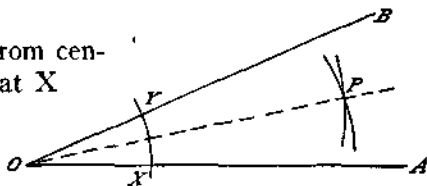
Shown at the right are **compasses**, an instrument used for the purpose of drawing a circle or an arc (which is part of a circle). A circle is divided into exactly 360 equal arcs, each of which is a unit arc measuring 1 degree. An arc is measured by the number of degrees it contains. You should distinguish between degrees of arc, which measure lengths of curved lines, and degrees of angle, which measure amounts of rotation of lines. However, an angle of 65° at the center of a circle will cut out of the circle 65° of arc, and so on. Thus we say: **A central angle has the same number of degrees as the arc it cuts out of the circle.**



I. Compasses can be used to divide an angle into two equal angles. This is called **bisection of an angle**.

Method:

- (1) Draw an arc XY from center O, cutting OA at X and OB at Y.
- (2) Draw equal arcs from X and Y. P is the intersecting point.
- (3) The bisector is OP.

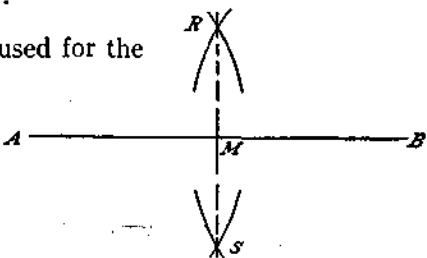


Angle AOP = angle POB.

II. Compasses are also used for the **bisection of a line**.

Method:

- (1) From center A, draw equal arcs, one above and the other below line AB.
- (2) Draw two more such arcs from center B.



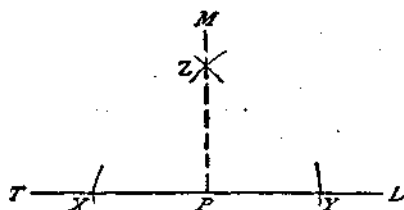
M is the mid-point of line AB.

Line AM = line MB.

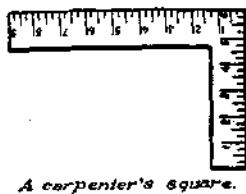
- (3) R is the meeting point of the upper set of arcs and S is the meeting point of the lower set.
 (4) The bisector is RS.

III. Construction of a right angle.

(a).



(b).



(a) **Problem:** To construct a line at right angles to line PL at point P, by using compasses.

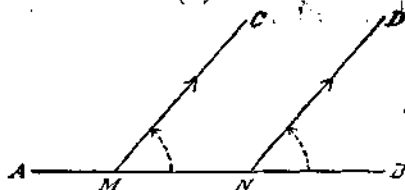
- (1) Extend line LP through point P, toward the left.
- (2) With P as center, draw equal arcs cutting line TL on either side of P, namely at points X and Y.
- (3) From points X and Y draw equal arcs above line TL, meeting at point Z.
- (4) Line PM drawn through Z forms a right angle with PL.

We call lines PL and PM a pair of **perpendicular lines**.

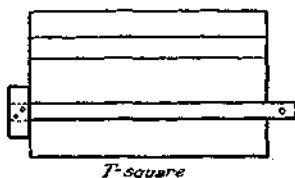
(b) The carpenter's square shown above is used for the purpose of getting right angles at the corners of boards.

IV. Parallel lines.

(a)



(b)



(a) The equal amounts of rotation of lines ND and MC from line AB give them the **same direction**. Two or more lines such as lines ND and MC are called a set of **parallel**

lines. The angles BND and BMC are in corresponding positions with relation to line AB and the parallel lines ND and MC, and they are named **corresponding angles**. We can conclude that: **Corresponding angles formed by parallel lines are equal.**

(b) If you intend drawing many plans, you will find the draftsman's T-square very convenient for making a number of parallel lines.

General Review of Measurement of Direction.

1. Draw an obtuse angle. Bisect the angle, using compasses, and then measure with a protractor the number of degrees in the original angle and in each part formed.

2. Draw a line $1\frac{3}{4}$ inches long. Bisect the line, using compasses, and then measure with ruler the length of each part formed.

3. Draw a horizontal line AB $1\frac{1}{2}$ inches long. With compasses, draw a line perpendicular to line AB at point B.

4. Draw a pair of parallel lines by using corresponding angles of 135° to the same horizontal base line.

5. Draw a right angle CMD with a protractor. Bisect the angle with compasses.

6. Draw a straight angle RPS. Bisect the angle with compasses.

7. Mark off an arc of 80° , an arc of 167° , on a circle of one inch radius.

8. How many degrees are there in the counter-clockwise change of direction, (a) from North to West; (b) from North to Southwest; (c) from South to East; (d) from Southeast to Northeast; and (e) from Northeast to West?

9. What is the number of degrees of arc in an easterly direction, (a) between 89° longitude west of Greenwich and 71° longitude west of Greenwich; (b) between 115° east longitude and 169° east longitude; (c) between 145° east longitude and 125° west longitude; and (d) between 138° east longitude and 169° west longitude?

10. What is the number of degrees of arc in a northerly direction, (a) between 20° latitude north of the Equator and 65° latitude north of the Equator; (b) between 85° south latitude and 45° south latitude; (c) between 15° south latitude and 35° north latitude; and (d) between 76° south latitude and 66° north latitude.

11. If there are 30 flowers around the edge of a circular flower plot, evenly spaced, how many degrees of arc are there between two successive flowers?

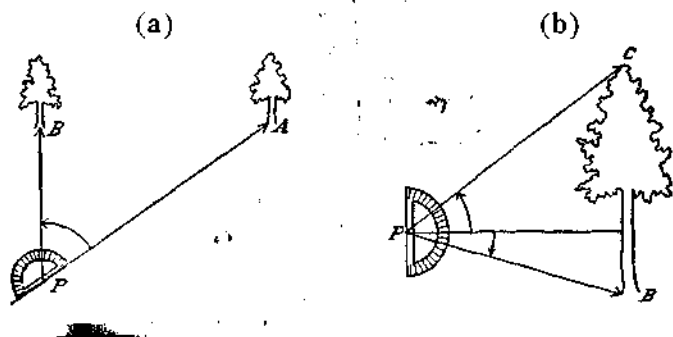
12. How many plants can be evenly spaced 24° apart around the edge of a circular plot?

13. Through how many degrees do you change direction, when you make a right turn; a left turn; an about face?

Some Surveying.

The standard surveying instrument used for measuring angles is the transit. The telescope of the transit with its cross hairs and a number of adjustments, such as levels, leveling screws, adjustment screws, clamp screws and verniers, serve to make the transit a precision instrument. It may be advisable to own a transit on a farm, where a sufficient need warrants its purchase. Selection can be made from a wide range of prices, depending upon the details of mechanical construction of the instrument.

In principle, the transit consists of two protractors, one horizontal and the other vertical.

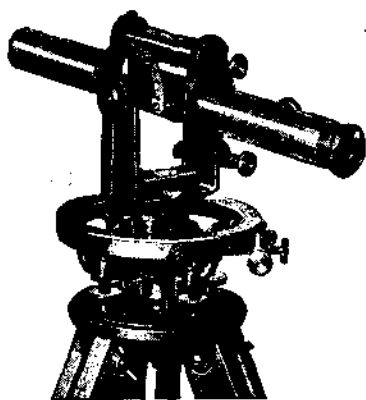


(a) Sight the instrument on tree A, with horizontal protractor at zero. Keeping the protractor fixed, sight the instrument on tree B, from the same point. Read the angle.

(b) When the instrument is level, the vertical protractor will read zero. Sight the top of tree C. Read the angle on the vertical protractor. This is called the **angle of elevation** from the horizontal line. The **angle of depression** from the horizontal line can be obtained from the same point by sighting the instrument on the bottom of the tree. You will be shown later how these angles are used in getting the heights of trees, when estimating timber.

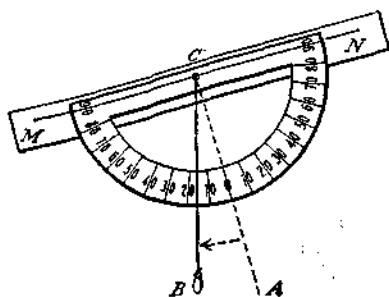
Leveling. Another use of the transit is in leveling. The purpose of leveling is to determine the difference of elevation (height above sea level) between two or more points. This requires a leveling rod, a vertical rod marked off in feet and smaller subdivisions. If the transit is sighted on the leveling rod, first held at point M and then held at point N, the difference in readings gives the difference in elevation of points M and N.

Leveling is important to the farmer in laying drains, planning irrigation and building roads. A **farm level** can be used instead of the transit, if the work does not need an extremely high degree of accuracy. It is a less expensive instrument than the transit. The usual level is also provided with a scale for reading vertical angles, and some farm levels even have a scale for reading horizontal angles. These angles can be read to the nearest degree, a sufficient accuracy for ordinary purposes. (Each degree on the transit is divided into 60 minutes; and each minute is subdivided into 60 seconds).



Farm Level

Rough angle measurements can be made with a **plumb protractor**. An inexpensive protractor can be attached to a narrow piece of wood, about 5 in. long. A piece of metal suspended from the center will hang in position A, when the protractor is held horizontally. M



and N are sharp points in line with the center, used as sights. When the instrument is sighted on the top of a tree, the change in position from A to B gives the angle of elevation. Similarly, for rough measurements of horizontal angles, it is simple to construct and use a protractor and sights mounted horizontally. In fact, a person with fair mechanical ability should be able to construct a farm level for practical use.

Projects in Actual Measurement.

I. Measure the following angles "to the nearest degree" in this manner:

- (a) Make the measurement three times with a protractor, and compare the three readings.
 - (b) Measure three times with a home-made farm level or transit, and compare these readings.
 - (c) Measure three times with a commercial farm level or transit, and compare these readings.
 - (d) Compare the results of the readings on the different instruments.
- (1). The horizontal angle between two sides of a building, meeting at a corner;
 - (2). A second corner of the same building;
 - (3). The angle at a corner of a field;
 - (4). A second corner of the same field;
 - (5). The angle of elevation of the top of a tree, and the angle of depression of the same tree, taken from the same point;

(6). The angle of elevation of the top of a telephone pole, and the angle of depression of the same pole taken from the same point.

II. Construct a leveling rod 8 feet long and 4 inches wide. Mark off the rod in feet and tenths of a foot.

(1). Measure the difference in elevation between the top and the bottom of a small incline, as follows:

- (a) Set an instrument (use the most accurate instrument available) at about the center of the incline, and fix the sight in a horizontal position.
- (b) Keeping the sight horizontal, sight the leveling rod, held vertically at the top of the incline. Record the reading of the leveling rod.
- (c) Keeping the instrument in the same position and the sight horizontal, read the leveling rod, now held vertically at the bottom of the incline.
- (d) Subtract the readings in (b) and (c).

REFERENCES

Field Work in Mathematics, by Shuster and Bedford, American Book Co.

Bulletins:

Measurement and Calculation of Field Areas, by D. G. Carter. Arkansas Exp. Sta. Ext. Cir. No. 325.

Simple Problems in Land Measurement, by E. G. Welch. Kentucky Agr. Exp. Sta. Cir. No. 291.

Chapter III

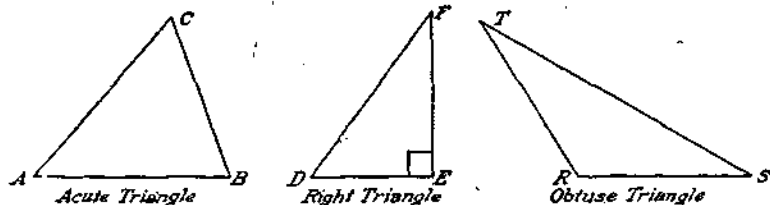
MEASUREMENT OF AREAS

STUDY the portion of the map of the United States below. You will notice that the different states have many kinds of shapes.



The map of your farm or school grounds probably also shows many different kinds of shapes. Before we can consider areas, we must learn to recognize and draw a number of surface forms. Some fields have triangular shapes.

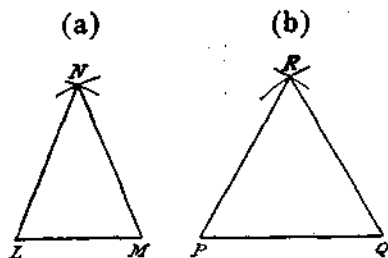
Kinds of Triangles



I. This classification of triangles is according to their kinds of angles. We read a triangle by its three vertices.

- (1) An **acute triangle** has only acute angles. (Tr. ABC)
- (2) A **right triangle** has a right angle. (Tri. DEF)
- (3) An **obtuse triangle** has an obtuse angle. (Tri. TRS)

II. Triangles are classified according to the lengths of their sides. The sides of a triangle are the three straight lines by which the triangle is bounded. In each triangle shown at the bottom of the previous page, each side has a different length from every other side of the same triangle.



(a) An **isosceles triangle** has two equal sides (See LMN). Isosceles triangle LMN was constructed by drawing equal arcs from points L and M.

(b) An **equilateral triangle** has three equal sides (See PQR). Equilateral triangle PQR was constructed

by drawing arcs from points P and Q each equal in radius to the length PQ.

Mathematical proof shows that: **The sum of the three angles of any triangle, no matter what size or shape the triangle, equals 180° .** To check this statement, draw a triangle and measure its three angles. Is your total about 180° ? You can check this another way, by cutting out the three angles of a triangle and pasting them next to each other.



Study in Triangles and their Angles.

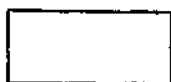
1. Draw a right triangle. Use compasses for 90° angle.

2. Draw an equilateral triangle. Measure each angle.
3. How many degrees are there in an angle of a triangle, if the other two angles each equal (a) 40° ; and (b) 65° .
4. Find one of two equal angles of a triangle, if the third angle equals (a) 60° ; (b) 120° ; and (c) 85° .

Quadrilateral is the name of the shape of a four-sided field. Several kinds of quadrilaterals appear below.



Parallelogram



Rectangle

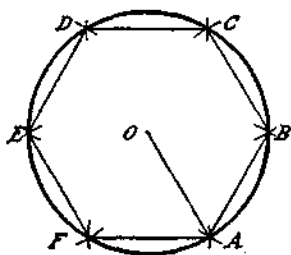


Square



Trapezoid

- (a) Parallelogram: both pairs of opposite sides are parallel; also both pairs of opposite sides are equal.
- (b) Rectangle: same as parallelogram; in addition, the angles of a rectangle are right angles.
- (c) Square: is a rectangle having all sides equal.
- (d) Trapezoid: only one pair of opposite sides are parallel. The cross-section of a watering trough or a trench silo are illustrations of the trapezoid.



Surfaces may be bounded by more than four sides. The six-sided figure, called the hexagon, is an arrangement used in planting orchards. The hexagonal and other methods of planting trees will be considered in detail later in this book.

The regular hexagon (equal in all angles and sides) can be drawn on paper by using compasses. After drawing the circle, start at any point A on the curve and mark off arcs successively, keeping the same length OA. You will find this fits exactly six times. The straight lines joining these successive points form the hexagon.

Practice in Drawing Figures.

1. Using the method explained on page 22, draw a regular hexagon having sides each $\frac{3}{4}$ in. long.

2. Draw a rectangle as follows: (1) draw a horizontal line AB $1\frac{1}{4}$ inches long; (2) using compasses, erect two perpendicular lines to line AB, one at the end A and the other at the end B, and mark off the length $\frac{3}{4}$ inch on each perpendicular; (3) draw a line between the two terminal points.

3. From the ends of a horizontal line, 2 in. long, draw a set of parallel lines, using a 35° angle. Measure one inch along each parallel, and then complete the parallelogram.

Perimeters of Triangles and Quadrilaterals.

It is often necessary to erect a fence enclosing a field. The linear measure of the **Perimeter** of the field indicates the length of fencing needed. To find the length of the perimeter, measure the length of each side of the field and then add these lengths. Therefore, the perimeter of any figure is the sum of the lengths of all its sides.

RULE 4.

(a) **Perimeter of a Triangle** = sum of its 3 sides.

(b) **Perimeter of a Quadrilateral** = sum of its 4 sides.

Do you have to measure the lengths of all four sides of a rectangle for the calculation of its perimeter? You can see that the amount of fencing needed for a field of rectangular shape can be found in a shorter way. If a field has a square shape, only one side has to be measured in order to find the perimeter.

RULE 4.

(c) **Perimeter of a Rectangle** = twice the length + twice the width.

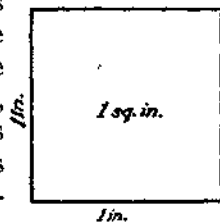
(d) **Perimeter of a Square** = 4 times the length of its side.

Lengths of Fences and other Problems in Perimeters.

1. How many yards of fencing are needed to enclose a triangular field that has sides, 85 ft., 72 ft. and 96 ft.?
2. Find the length of fencing needed for a triangular field, if the sides measure $31\frac{1}{4}$ ft., $64\frac{1}{2}$ ft. and $79\frac{3}{4}$ ft.
3. What is the amount of fencing for a square field, if its side measures: (a) 12 rd., (b) 79 yd., (c) $\frac{1}{8}$ th of a mi.?
4. What is the outside length of the concrete foundation of a building 34 ft. wide and 69 ft. long?
5. How much baseboard is needed for a room 15 ft. 8 in. wide by 22 ft. 7 in. long?
6. How much fencing is needed to enclose a rectangular field 87 rd. 6 ft. long by 35 rd. 12 ft. wide?
7. Find the amount of fencing for a field having the shape of a parallelogram, if it measures 43 yd. 2 ft. along the short side and 63 yd. 1 ft. along the long side.

What is the acreage of a certain field you intend to lime? How much land space is taken up by the potato crop? In constructing a concrete walk, over how much surface must the concrete be spread?

To answer these questions, and many others about the farm, you must learn square measure. The **area** of a figure is the quantity of surface enclosed by its boundaries. Units of area had to be invented to measure amounts of surface. For several thousand years the square has been used as the unit of area. The length of the square is some unit of length. For example, when the length of the side of the square is 1 in., the square measures 1 square inch (sq. in.), shown at the right. The number of times you can fit this unit over the surface of this page measures the area of this page. However, a more suitable unit for the measurement of the area of the side of a house that may need painting is 1 square foot (sq. ft.), and the square mile would be the most convenient unit for measuring the area of a township.



The relationships between different units of square measure appear below.

Square Measure

144 sq. in. = 1 sq. ft.	160 sq. rd. = 1 acre (A) *
9 sq. ft. = 1 sq. yd.	640 acres = 1 sq. mi.
$30\frac{1}{4}$ sq. yd. = 1 sq. rd.	36 sq. mi. = 1 township
One acre equals $160 \times 30\frac{1}{4} \times 9$, or	
1 acre = 43,560 square feet.	

It becomes necessary once more to change from one unit to another. The process is the same method of **conversion** used in the exchange of linear units, except that a different set of **conversion factors** is used, namely, the numbers in the above table. The rules of conversion of units of square measure are the same **Rule 1.** and **Rule 2.** of pages 2, 3 of this book. A square measure is changed to a higher denomination by multiplication, and to a lower denomination by division by the conversion factor.

PRACTICE IN CONVERSION OF MEASUREMENTS OF AREAS

1. Memorize all the conversion factors of square measure found on this page.
2. Study Rule 1. and Rule 2., appearing on pages 2, 3. Use the same rules for the following examples, but employ the **conversion factors of square measure.**
 3. Change 24 sq. ft. to sq. in.; 14 sq. yd. to sq. ft.
 4. Change 52 sq. ft. to sq. in.; 27 sq. yd. to sq. ft.
 5. Change 9 sq. yd. to sq. in.; 16 sq. rd. to sq. yd.
 6. Change 12 sq. yd. to sq. in.; 12 sq. rd. to sq. yd.
 7. Change 5 acres to sq. rd.; then to sq. yd.
 8. Change 13 acres to sq. rd.; this answer to sq. yd.
 9. Change 5 sq. mi. to acres; 2 acres to sq. ft.

* The acre is not necessarily a square, but can be any shape, provided it contains 160 sq. rd. This is the one exception to the requirement that a unit of area is a square.



An Acre of Potatoes at the Newtown High School Farm.

10. Change 12 sq. mi. to acres; 4 acres to sq. ft.
11. Change 2304 sq. in. to sq. ft.; to sq. yd.
12. Change 4320 sq. in. to sq. ft.; to sq. yd.
13. Change 648 sq. ft. to sq. yd.; 605 sq. yd. to sq. rd.

For the second parts of this and the next examples, use the method of dividing by a fraction.

14. Change 3024 sq. ft. to sq. yd.; 1331 sq. yd. to sq. rd.
15. Change 1120 sq. rd. to acres; 4480 acres to sq. mi.
16. Change 2080 sq. rd. to acres; 5120 acres to sq. mi.
17. Study the illustrations on pages 3, 4 for expressing a lower denomination as a fraction of a higher denomination. Do the following set of examples in the same way, but use the **conversion factors of square measure**.
18. What part of a sq. ft. is 12 sq. in.?
19. What part of an acre is 20 sq. rd.?
20. What part of a sq. mi. is 80 acres?
21. What part of a sq. mi is 80 sq. rd.?

Section of a Township. A township is divided into 36 equal squares, called sections. Each section equals $\frac{1}{36}$ th of a township, or 1 sq. mi. This method of survey, adopted by congressional act, is used mostly in western states.

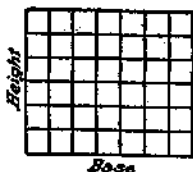
22. Find the number of acres in (a) $\frac{1}{2}$ section, (b) $\frac{1}{4}$ section, (c) $\frac{1}{8}$ section, (d) $\frac{3}{4}$ section.

23. What part of a section is (a) 40 acres, (b) 240 acres, (c) 400 acres, and (d) 280 acres.

Finding the Area of a Rectangle.

The ruler and the tape automatically find the number of times a linear unit fits into a certain length. What instrument would automatically count the number of times the square inch fits over the surface of this page, or the number of times the square rod fits over the surface of a large field containing a crop of full grown corn? Direct measurement of area on the farm is impracticable.* Therefore, the problem to be solved now is to **measure area indirectly**.

The horizontal dimension of a rectangle is called the **base**, and the vertical dimension is called the **height**. Draw on squared paper a rectangle having a base of 7 units and a height of 6 units. By actual counting, the rectangle has an area of 42 square units because it contains the unit of area 42 times. However, the count of the total number of square units contained in the rectangle can be shortened. Since the base is 7 units long, there are 7 rows of square units, and likewise there are 6 square units in each row because the height is 6 units long. Thus the total number of square units contained in the rectangle is 7×6 , or 42 square units.



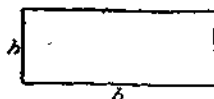
You can see that there are as many rows of squares as the number of linear units in the base of the rectangle, and as many squares in each row as there are linear units in the height. Therefore, it is unnecessary to use squared paper or to mark up a rectangular field into squares, as area can be found by measuring the number of linear units in the base and in the height, and by multiplying these two dimensions.

* An instrument, called the planimeter, is sometimes used for the direct measurement of irregular areas on paper.

RULE 5. The area of a rectangle equals the product of the base by the height.

Rule 5., abbreviated in the mathematical shorthand, the formula, is written

$$A = bh$$



b means the base, h means the height, and although no multiplication sign is used between b and h , bh means the base multiplied by the height. The formula is a convenient method of stating a rule in condensed form, and is very helpful in memorizing the rule.

The dimensions of a rectangle often are also written in abbreviated form. If a rectangle is 85 feet long and 72 feet wide, this can be written as $85' \times 72'$, reading 85 feet by 72 feet; and $46'' \times 59''$ reads 46 inches by 59 inches. Note that it does not matter which dimension is considered the base and which the height, as the product of two numbers is the same in whichever order the two numbers are multiplied.

PRACTICE IN COMPUTING THE AREAS OF RECTANGLES

1. How many acres are there in a rectangular field, if $b = 80$ rd. and $h = 60$ rd.?

SAMPLE

$$A = bh$$

Cancel:

METHOD

$$b = 80 \text{ rd.}$$

$$A = 80 \times 60 \text{ sq. rd.}$$

$$80 \times 60$$

$$h = 60 \text{ rd.}$$

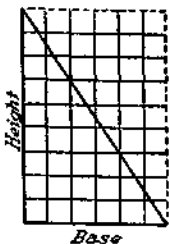
$$A = 30 \text{ acres}$$

$$\frac{80 \times 60}{160}$$

2. How many square yards are there in a rectangular lot, if the base measures 180 feet and the height 60 feet?
3. What is the selling price of a rectangular plot of land, $40 \text{ rd.} \times 100 \text{ rd.}$, sold for \$75 per acre?
4. What is the cost of a farm of rectangular shape purchased for \$35 per acre, measuring 3 mi. long and 2 mi. wide?

Finding the Area of a Triangle.

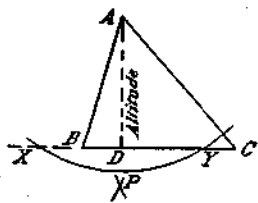
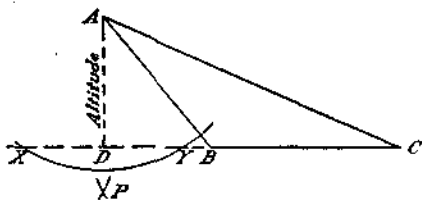
The dimensions of a right triangle are the **base** and **height** (also called the **altitude**). As is likewise true for the rectangle, the base and height of a right triangle are always at right angles to each other. Draw on squared paper a right triangle having a base of 6 units and a height of 9 units. Can you count the number of square units in the triangle? To avoid this difficulty, draw the dotted lines shown in the diagram at the right and you have thus formed a rectangle. What part of this rectangle is the area of the right triangle? By the formula, $A = bh$, the area of the rectangle is 54 square units; then the area of the right triangle is $\frac{1}{2}$ of 54, or 27 square units.



RULE 6. The area of a right triangle equals one-half of the product of its base and height.

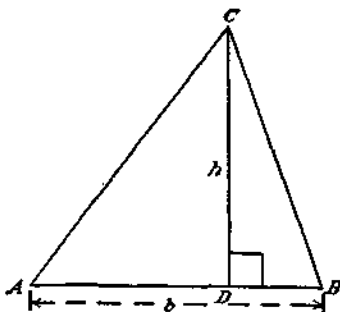
$$\text{FORMULA: } A = \frac{1}{2} bh \text{ or } A = \frac{bh}{2}$$

Any kind of triangle has a **base** and **height (altitude)**. When you draw any triangle, except a right triangle, the altitude does not appear on the original figure. The altitude must be drawn perpendicular to the base. This perpendicular line may be sketched in free hand, but for an accurate result, the compasses should be used.

I. Altitude of an Acute Triangle.**II. Altitude of an Obtuse Triangle.**

The above construction is called dropping a perpendicular from a point to a line. Try using the protractor instead of compasses.

At the right is triangle ABC having base $AB = b$ and altitude $CD = h$. The altitude divides the triangle into two right triangles, ADC and DBC. By Rule 6, the area of each triangle equals $\frac{1}{2}$ of the product of its base and height. The height of each triangle is h , which is also the height of the whole triangle ABC. The



base of each right triangle is a portion of base b , and the sum of these two portions of b equals the whole base b . Addition of the two right triangles results in the following rule for the area of an entire triangle ABC.

RULE 7. The area of any triangle equals one-half of the product of its base and height.

FORMULA: $A = \frac{1}{2}bh$ or $A = \frac{bh}{2}$

Testing the Formula.

Draw an acute triangle and letter it ABC, as in the above figure. Using compasses, construct altitudes from vertex C to base AB and from vertex A to base BC. Measure AB, BC, and their corresponding altitudes. Check the formula $A = \frac{1}{2}bh$ by calculating the area of triangle ABC from each pair of altitude and base. May you use any side of a triangle as its base in calculating the area of the triangle, provided you use the corresponding altitude?

Practice in Computing Areas of Triangles.

1. How many acres are there in a triangular field, if its base is 30 rd. and its altitude is 48 rd.?

SAMPLE PLAN

and
METHOD

$b = 30$ rd.
 $h = 48$ rd.

$$A = \frac{bh}{2} \quad \begin{array}{l} \text{Cancel.*} \\ 30 \times 48 \\ 2 \times 160 \end{array}$$

$$A = \frac{30 \times 48}{2}$$

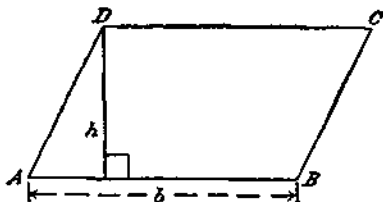
$$A = 4\frac{1}{2} \text{ acres } \textit{Answer.}$$

* 2. Work out Special Drill number 4 on page 271, in cancellation of fractions.

3. The altitude of a triangular lot is 90 ft., and the base is 125 ft. Find the area in square feet; in sq. yd.
4. What is the value of a triangular plot, at \$72.50 per acre, if $b = 270$ rods and $h = 64$ rods?

Finding the Area of a Parallelogram.

The altitude of a parallelogram is the perpendicular distance between its two parallel bases. At the right is a parallelogram, having its base $AB = b$ and altitude h . If the diagonal DB of parallelogram $ABCD$ is drawn, it divides the figure into two equal triangles. The area of triangle $ABD = \frac{1}{2}bh$. Parallelogram $ABCD$ has twice the area of the triangle; therefore the area of the parallelogram is twice $\frac{1}{2}bh$, or exactly bh .



RULE 8. The area of a parallelogram equals the product of its base and height.

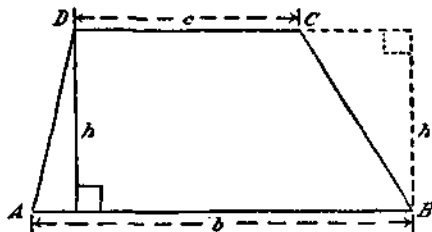
FORMULA: $A = bh$.

What is the area of each of the following Parallelograms?

- | | |
|-----------------------------|-------------------------------|
| 5. $b = 38'$, $h = 82'$. | 7. $b = 27$ yd., $h = 71$ ft. |
| 6. $b = 6'3''$, $h = 8'$. | 8. $b = 75$ rd., $h = 80$ rd. |

Finding the Area of a Trapezoid.

The two parallel lines of a trapezoid are its bases, and its altitude is the perpendicular distance between the bases. Trapezoid $ABCD$, at the right, has bases $AB = b$ and $CD = c$, and altitude h . When diagonal DB is drawn, it divides the trapezoid into two triangles. Triangle ABD has base b and altitude h ,



and triangle BCD has base c and also the same altitude h . As the area of the trapezoid is the sum of the areas of these two triangles, its area equals the sum of $\frac{1}{2}bh$ and $\frac{1}{2}ch$, which reduces to $\frac{1}{2}(b+c)h$.

RULE 9. The area of a trapezoid equals one-half of the product of the sum of its bases by the altitude.

FORMULA: $A = \frac{1}{2}(b+c)h$ or $A = \frac{(b+c)h}{2}$

Practice in Computing the Areas of Trapezoids.

1. What is the area of the cross-section of an irrigation supply ditch having the shape of a trapezoid, if the bases are 44" and 24", and the height is 9".

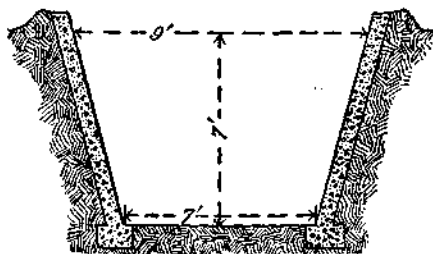
SAMPLE PLAN and METHOD	$b = 24''$	$A = \frac{(b+c)h}{2}$	Cancel: $\frac{68 \times 9}{2}$
	$c = 44''$	$A = \frac{(24+44) \times 9}{2}$	
	$h = 9''$		

$A = 306$ sq. in. *Answer*

2. What is the cross-sectional area of an irrigation supply ditch, if the trapezoid measures 30" and 16" across the top and bottom respectively, and is 6" in height?

3. Find the cross-section of a supply ditch, if the bases of the trapezoid are 10' and 6', and the height is 18".

4. As appears in the illustration, the cross-section of a trench silo has the shape of a trapezoid. Find the area of the trapezoid, when it is 9 ft. wide at the top, 7 ft. wide at the bottom and 7 ft. deep.



5. What is the area of the cross-section of a trench silo, measuring 12' and 8' across the top and bottom respectively, and 8' in height.

Finding the Area of a Square.

The square is a special kind of rectangle. As it has all sides equal, the base and height are both the same length. Thus, instead of using the letters b and h for the base and height, we can represent each of these lines by the same letter s . Applying the formula for the area of a rectangle, the area of a square equals $s \times s$. In mathematical shorthand, this is written $A = s^2$, and reads: "**A equals s square,**" or "**s to the second power.**" The letter s is called the base, and the number 2 is called the exponent.

RULE 10. The area of a square equals the square of its side.

FORMULA: $A = s^2$

If the edge of a square tile is 6 inches, the area of its surface is 6^2 , which equals 6×6 , or 36 square inches. The number 6 is the base, 2 is the exponent and 6^2 reads **6 square**.

Practice in Computing the Areas of Squares.

1. Read each of the following, and name the base and the exponent: (a) 8^2 , (b) 4^2 , (c) 9^2 , (d) k^2 , (e) r^2 , (f) 64^2 .
2. How many acres are contained in a square farm, if the length of the farm is 120 rods?

SAMPLE

PLAN

$s = 120$ rd.

$A = s^2$

$A = 120 \times 120$

A = 90 acres

Cancel:

120×120

160

3. Find the areas of each of the following squares: (a) $s = 13$ ft., (b) $s = 83$ ft., (c) $s = 5\frac{1}{2}$ mi., (d) $s = 6'3''$.*
4. A building 50 ft. by 46 ft. is built on a lot 100 ft. square. How much remains for the grounds and the garage?
5. A square field, 96 ft. on a side, is divided into experimental plots $8' \times 12'$ each. How many plots are there?

* 6. Work out Special Drill number 5, on page 271, in multiplication of fractions.

General Problems in Areas.

7. How many tiles, each 8 inches square, are needed to tile a floor 12 ft. by 16 ft.?

8. A road 10 feet wide and 120 rods long is paved with blocks 4" x 8". How many such blocks are needed?

9. The outside dimensions of a concrete floor of a chick brooder house are 9'3" x 13'4". What is the area of the concrete used? (Change the inches to fractions of a foot).

10. Find the number of square feet in the gable end of a house (triangle) which has a base 16'6" and a height 8'3".

11. How many gallons of paint are needed for a fence 6 ft. high and 75 ft. long, if one gallon will cover 25 sq. yd.?

12. What is the cost of shingle stain for a rectangular roof, 30' x 24', at \$1.44 a gallon, when one gallon will cover 24 square yards.

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Chapter IV

PRACTICAL LAND MEASUREMENT

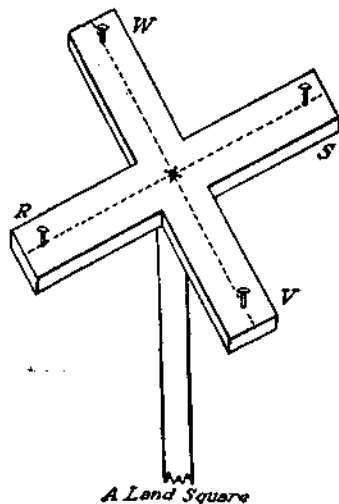
LAND measurement is fairly simple if the field has a standard shape, with straight lines as boundaries. First, you must check the shape of the field to determine which formula for area is suitable. Then, accurately measure those dimensions of the field required by the formula. Finally, you calculate the area by means of the formula, as explained in the previous chapter.

Measuring a Field of Standard Shape.

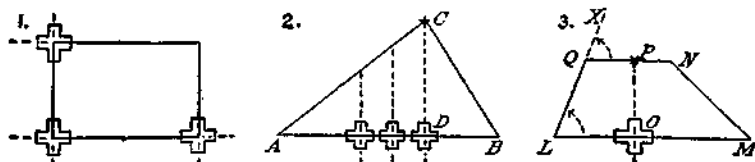
1. The Rectangular Field. Check at least three corners of the field for right angles. A commercial or even home-made transit can be used for this purpose. Another instrument, the angle mirror, is specifically designed for determining right angles. If none of these instruments are available, you can easily make a substitute device.

A **land square** is a simple instrument to construct, at very little cost. The two cross-arms must be set exactly at right angles. R, S, V and W are sharp points, used as sights. RS and VW should each be in the exact center of the arm. Attach the square horizontally to a 5-foot rod, pointed at the bottom. Poles, about 6 feet long, can be used as sighting rods.

To check the angle at a corner of the field, thrust the instrument into the ground at that corner. Fix a sighting rod at



Using the Land Square.



each of the two adjacent corners of the field. If each sighting rod is in line with a pair of sights (RS or VW) on the square, which is kept in a fixed horizontal position, the angle is a right angle.

Measure the base and height of the field in the manner shown in Chapter I, and then compute the area by formula.

2. The Triangular Field. If one angle of the triangle proves to be a right angle, then the field is a right triangle in shape. Measure the two sides of the triangle which form the right angle. Name either one the base and the other the altitude, and compute the area of the triangle by formula.

The land square simplifies the problem of finding the altitude of a triangle of any shape. Use any side of the triangle as the base; the height is the perpendicular line from the opposite vertex to this line. As illustrated above, place a sighting rod at vertex C. Walk along base AB, while sighting one arm of the square along this line. At intervals along AB, sight for point C on the other arm of the square. Place a marker at the point on base AB where C and B are both in sight on the instrument. Measure the length of AB, the base, and CD, the altitude, and then calculate area by formula.

3. The Trapezoid and the Parallelogram. First, check these shapes for opposite pairs of parallel lines: one pair for the trapezoid, and two pairs for the parallelogram. For each pair of parallel lines, show that a set of corresponding angles are equal, for example, angles MLX and NQX in diagram 3.

Use the land square to find the altitude of either the trapezoid or the parallelogram as follows. Fix the instrument at any convenient point along one line of a set of parallels. As

an illustration, take point O on line LM. With one arm of the square sighting along LM, have a marker placed at point P in line with the cross-arm of the square. Measure the length of OP, the altitude.

For the trapezoid, measure the length of the lower and upper bases; for the parallelogram, measure the length of one base (opposite sides of a parallelogram are equal). Compute area by means of the appropriate formula.

Measuring a Field of Irregular Shape.



1 rectangle, 1 triangle



3 triangles



1 trapezoid, 2 triangles.

A field of irregular shape may be divided into triangles, rectangles and trapezoids. Just how to make the subdivisions depends on your own judgment. Careful planning in advance on paper will save you considerable time and effort, by avoiding extra measurements. See the above figures.

Often boundaries of fields are broken or curved lines. By careful placement of an "average" straight line which approximately balances the amounts of area on both sides of the line, you can arrive at a fairly accurate result.



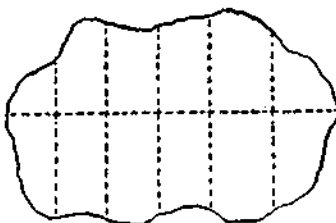
Triangle



Parallelogram

This is shown in the diagrams at the right by the solid oblique lines.

For a completely irregular area, the method of offsets can be used. Select a base line across the field. Mark off perpendiculars to the base line at convenient intervals. Add the areas of the subdivisions (all trapezoids except at the ends).



Instruments. Some land measurement requires the use of an instrument for the measurement of horizontal angles. In many places, commercial instruments are not available, nor even necessary for fairly approximate measurement. Also, construction of too many home-made instruments may be inconvenient. Instead of having a land square for right angles and a horizontal protractor for angles of any size, the land square can be modified to do either task. Make one arm movable, and attach a protractor to measure the rotation.

Projects in Land Measurement.

I. Make all the necessary measurements, and compute the number of acres in fields shaped as follows:

1. Rectangle.
2. Triangle.
3. Trapezoid.
4. Parallelogram.

II. Draw a plan for subdivision of an irregular shaped field with straight line boundaries into standard shapes.

- (a) Make all the necessary measurements for the area of each subdivision.
- (b) Calculate the area in acres of each subdivision.
- (c) Calculate the area in acres of the entire field.

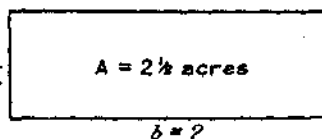
III. Find the area in acres of a field having one curved line boundary, by using an "average" straight line in place of the curved line.

IV. Find the acreage of a completely irregular area by the method of offsets.

To Lay Out a Rectangular Field of a Desired Area.

1. **SAMPLE METHOD** for laying out a rectangular field.

Plan the length of a field, if the desired area is $2\frac{1}{2}$ acres, and the width of the field is 178 feet.



- (a) 1 acre = 43,560 sq. ft.

$$2.5 \times 43,560 = 108,900 \text{ sq. ft.}$$

- (b) $b = A \div h$. $b = 108,900 \div 178 = 611.79 + \text{ft.}^*$

* 2. Work out Special Drill number 10, on page 274, in division.

- (c) Round off the answer to the nearest tenth of a ft.
 $611.79 \div \text{ft.}$ becomes 611.8 ft. (See pages 7 and 8.)

Answer: Make the length of the field 611.8 ft.

Note: To find h when b is given, use the formula, $h = A \div b$, in exactly the same way.

3. Plan the layout of the following rectangular fields:

- (a) $A = 3$ acres, $b = 363 \text{ ft.}$, find h .
- (b) $A = 4.5$ acres, $h = 405 \text{ ft.}$, find b .
- (c) $A = 2$ acres, $b = 293 \text{ ft.}$, find h .
- (d) $A = 5.5$ acres, $h = 282 \text{ ft.}$, find b .
- (e) $A = 4$ acres, $h = 317 \text{ ft.}$, find b .

SQUARE FIELDS.

You want to mark off a square field containing one acre. What should be the length of the side of the field? How long must you make the side of a square field, to contain any desired area?

To solve this problem, we must refer back to the formula for the area of a square: $A = s^2$. When the side of a square is 3 in., its area equals the square of 3, which is 3×3 , or 9 square inches. In general, to find the area of any square, take the square of its side.

In your early training in mathematics, you learned four fundamental operations, that is four processes of reckoning. They are: addition and its inverse, subtraction; and multiplication and its inverse, division. **Squaring a number** is a fifth operation. When two or more numbers are multiplied together, they are called factors of the product. The numbers 5 and 7 are called the factors of 35, because $5 \times 7 = 35$, and so forth. A number is called a **square** when it is the product of **two equal factors**. For example, $5 \times 5 = 25$; the number 25 is the square of 5.

When a number is squared, the process is equivalent to finding the area of a square if that number represents the side of the square. However, squaring a number is useful in other connections, and it is important to be skilled in the process of

squaring a number for other purposes besides finding the area of a square.

Practice in Squaring Numbers.

1. Make a table of the squares of all numbers from 1 to 25. Write the numbers from 1 to 25 in one column, and the respective square of each number in a second column.

2. Find the areas of each of the following squares:

- | | |
|------------------|---------------------|
| (a) $s = 77$ rd. | (c) $s = 21.3$ ft.* |
| (b) $s = 56$ yd. | (d) $s = 41.9$ ft. |

3. Square the following numbers:

- | | | | |
|---------|---------------------|-----------|-----------|
| (a) 146 | (d) $8\frac{1}{2}$ | (g) 53.3* | (j) 3.42 |
| (b) 297 | (e) $5\frac{2}{7}$ | (h) 138.6 | (k) 8.19 |
| (c) 368 | (f) $15\frac{1}{2}$ | (i) 397.8 | (l) 26.54 |

* 4. Work out Special Drill number 8, on page 273, in multiplication of decimals.

To Lay Out a Square Field of a Desired Area.

How long must you make the side of a square, to contain an area of 36 square inches, 16 sq. in., 25 sq. in.? You must find one of the two equal factors of 36, 16 and 25. The length of the side of a square of 49 square feet is 7 ft., because $7 \times 7 = 49$. This process, which is the inverse of squaring a number, is called: "extracting the square root of a number." It is a sixth fundamental operation, and is indicated by the sign $\sqrt{\quad}$. $\sqrt{64}$ reads: "the square root of 64."

RULE 11.

- To extract the square root of a number, find one of the two equal factors of the number.
- To find the length of the side of a square of a given area, extract the square root of the number of square units in its area.

A Perfect Square is a number which is exactly the product of two equal factors. The square root of small numbers which are perfect squares can be taken by inspection. In fact, you can use the table you made for ex. 1, this page.

- (a) $\sqrt{36} = 6$, because $6 \times 6 = 36$.
 (b) $\sqrt{16} = 4$, because $4 \times 4 = 16$.
 (c) $\sqrt{25} = 5$, because $5 \times 5 = 25$.
 (d) $\sqrt{.81} = 0.9$, because $0.9 \times 0.9 = 0.81$.
 (e) $\sqrt{.04} = 0.2$, because $0.2 \times 0.2 = 0.04$.

For larger numbers which are perfect squares, the following method may be used:

Find the length of the side of a square of 1369 sq. ft.

- (1) $\sqrt{1369}$ is between 30 and 40, because $30^2 = 900$,
and $40^2 = 1600$.
- (2) The number might be 31, 32, 33, 34, or 35, etc.
- (3) The number must be either 33 or 37, because only 3×3 or 7×7 could give a product ending in 9, and the number 1369 ends in 9.
- (4) By actual multiplication, $\begin{array}{r} 33 \\ \times 37 \\ \hline \end{array}$

$$\begin{array}{r} 33 \\ \times 33 \\ \hline \end{array} \quad \begin{array}{r} 37 \\ \times 37 \\ \hline \end{array}$$

the square root of $1369 = 37$, because $37 \times 37 = 1369$. Answer: The side of the square is 37 ft.

Practice in Extracting the Square Roots of Numbers.

1. Memorize the square root of each perfect square (whole number) from 1 to 400 (use the table you made).
2. Find the following square roots by inspection, and check by squaring each answer:

(a) $\sqrt{0.25}$

(c) $\sqrt{0.09}$

(e) $\sqrt{1.44}$

(b) $\sqrt{0.36}$

(d) $\sqrt{0.01}$

(f) $\sqrt{2.56}$

3. Find the square roots of the following numbers by the method shown in steps (1) to (4) on this page, and check by squaring each answer:

(a) 961

(c) 1764

(e) 2809

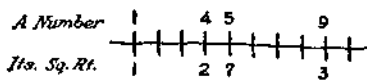
(b) 784

(d) 3136

(f) 4761

The Approximate Square Root of a Number.

You cannot extract an exact square root of every number. The square root of $4 = 2$ and the square root of $9 = 3$, but the square root of any number between 4 and 9, such as 5, must be some number between 2 and 3.



3. What is the value of the square root of 5?

To find $\sqrt{5}$, try different values between 2 and 3. Check each estimate by squaring. You could try as follows:

2.1 2.2 2.3 Notice that the use of 2.2 brings the result nearer to 5, but that 2.3 is too large.

This places the value of $\sqrt{5}$ between 2.2 and 2.3. Again, try different values, this time between 2.2 and 2.3.

2.21 2.22 2.23 2.24 We get closer and closer to 5 by the successive use of 2.21, 2.22, etc., until we find that 2.24 is too large.

You can attempt to find $\sqrt{5}$ more accurately, by using decimals 2.231, 2.232, 2.233, 2.234, etc., but you will not be able to get an exact answer. Only an approximate answer can be found for $\sqrt{5}$, and for the square roots of many other numbers. Such numbers are called **irrational numbers**.

$\sqrt{5} = 2.24$, to the nearest hundredth, by rounding off 2.236.

$\sqrt{5} = 2.2$, to the nearest tenth, by rounding off 2.23.

A more convenient way of extracting the square root of any number:

1. Separate the number into groups of two figures, moving to the left and the right from the decimal point. A single figure at the extreme left can constitute a whole group.

Bring up the decimal into the answer.

2. Find the largest perfect square (whole number) not more than the first group at the left. Write its square root directly over this group, as the first figure in the answer. Subtract the square from the first group.

3. Carry down the next group and place it at the right of the remainder.

4. Double the number in the answer and multiply by 10. The product formed is the trial divisor.

5. Divide the trial divisor into the result obtained in Step 3. Write this quotient in the answer over the group brought down in Step 3, and also add it to the trial divisor in the box on the left, to form the complete divisor.

6. Multiply the complete divisor by the last figure in the answer just obtained and subtract the product from the result in Step 3. (If the product is too large, change the last figure in the answer to the next smaller whole number.)

7. If there are more groups, carry them down one by one, and repeat Steps 4, 5, and 6, until the remainder is 0 or until the desired number of decimal places have been obtained.

Illustration: Find the square root of 2237.29.

1. The groups are 29, 37 and 22. Bring up the decimal into the answer.

2. The largest perfect square in 22 is 16. Write 16 under 22. $\sqrt{16} = 4$. Write 4 in the answer over 22.

3. Subtract 16 from 22. Carry down 37.

4. Trial divisor is $2 \times 4 \times 10 = 80$.

5. $637 \div 80 = 7 +$. Write 7 in the answer over 37. The complete divisor is $80 + 7 = 87$.

6. $87 \times 7 = 609$. Subtract 609 from 637.

7. Carry down 29. Trial divisor is $2 \times 47 \times 10 = 940$. $2829 \div 940 = 3$. Write 3 in the answer over 29. The complete divisor is $940 + 3 = 943$. $943 \times 3 = 2829$. Subtract from 2829. There is no remainder.

8. Check the answer by multiplying: 47.3×47.3 .

	4	7.	3
	$\sqrt{22\ 37.\ 29}$		
	16		
80	6 37		
7			
87	6 09		
940	28 29		
3			
943	28 29		

Find the square root of each number, and check the answers.

a. 1024

e. 21,904

i. 27.04

b. 2209

f. 34,596

j. 158.76

c. 3364

g. 93,025

k. 24.5025

d. 5184

h. 337,561

l. 9.2416

Use one group after the decimal for the square root "to the nearest unit," two groups after the decimal for "the nearest tenth" and three groups after the decimal for the "nearest hundredth." The extra place in the answer should be disposed of in the usual manner of rounding off: drop the extra place in the root if it is less than 5; increase the previous place in the root by one if the extra place is 5 or more.

I. Find $\sqrt{11}$ to the nearest hundredth.

$$\begin{array}{r} 3.316 \\ \sqrt{11.0000} \\ 9 \\ \hline 60 \quad 2 00 \\ \underline{3} \\ 63 \quad 1 89 \\ \hline 660 \quad 11 00 \\ \underline{1} \\ 661 \quad 6 61 \\ \hline 6620 \quad 4 39 00 \\ \underline{6} \\ 6626 \quad 3 97 56 \end{array}$$

II. Lay out a square field containing one acre.

$$\begin{array}{r} 208.71 \\ \sqrt{43560.0000} \\ 4 \\ \hline 400 \quad | \quad 3560 \\ \underline{8} \quad | \\ 408 \quad | \quad 3264 \\ \hline 4160 \quad | \quad 29600 \\ \underline{7} \quad | \\ 4167 \quad | \quad 29169 \\ \hline 41740 \quad | \quad 43100 \\ \underline{1} \quad | \\ 41741 \quad | \quad 41741 \end{array}$$

Answer: Make each side of the field 208.7 ft. How close is this approximation?

Find the square root to the nearest hundredth:

- | | | | |
|------|-------|---------|------------|
| 1. 2 | 5. 10 | 9. 15 | 13. 85.79 |
| 2. 3 | 6. 11 | 10. 31 | 14. 93.5 |
| 3. 6 | 7. 13 | 11. 147 | 15. 752.5 |
| 4. 7 | 8. 14 | 12. 259 | 16. 14.382 |

Plotting Square Fields.

Find the length of the side of a square field, containing each of the following areas. Calculate the length to the nearest tenth of a foot.

17. 1.5 acres	20. 3 acres	23. 4.5 acres
18. 2 acres	21. 3.5 acres	24. 5 acres
19. 2.5 acres	22. 4 acres	25. 5.5 acres

The Square Root Table.

A table of square roots of numbers from 1 to 100, and of the squares of numbers from 1 to 100, appears on page 281.

26. Use the table on page 281 to check the answers you obtained for examples 1 to 10 on the previous page.

Projects in Laying Out Fields.

- I. Stake out a square field containing one acre.
- II. Stake out a square field containing two acres.
- III. Stake out a rectangular field containing 1.5 acres, on a base of 300 feet.
- IV. Stake out a rectangular field containing 2.5 acres, on a base of 400 feet.

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Simple Problems in Land Measurement, by E. G. Welch. (See References, Chap. II.)

Chapter V

THE PLANTING OF CROPS AND ORCHARDS

Planting in Checked Rows.

WHEN planting is done in checked rows, the rows run along the length and the width of the field, forming a network of squares or rectangles. A plant or hill is placed at each corner of a rectangle. A part of a field containing twelve hills in checked rows is shown at the right. Each hill is indicated by a small number at a corner of a rectangle.

How much space is needed in this type of planting? Suppose the twelve hills shown in the above diagram were sweet corn, planted 3 feet each way. Then each hill requires 9 square feet (3×3) of space. If we assume that Hill 1. takes Square 1., Hill 2. takes

1	2	3
4	5	6
7	8	9
10	11	12

Square 2., etc., then the full space is accounted for, with provision for a suitable border, $1\frac{1}{2}$ feet in width, all around.

Number of Plants Per Acre.

You have just been shown the amount of space required in planting by checked rows. You can presume that each hill uses the area of a rectangle. The base and height of the rectangle are the respective distances between the rows, each way. Base times the height gives the area of each rectangle, and the total area of one acre equals 43,560 sq. feet. The rule for finding the number of plants per acre now follows.



An Excellent Crop, Copenhagen Market Type of Cabbage, in Checked Rows.

Robson Seed Farms.

RULE 12. To find the number of plants per acre:

- (a) Compute the number of square feet in the area of a rectangle, using the respective distances each way between the rows as base and height;
- (b) Divide 43,560 sq. ft. by the number of square feet in the rectangle occupied by each hill;
- (c) If more than one plant to the hill, multiply the total number of hills by the number of plants to the hill.

In many cases, the division into 43,560 will result in a remainder. This amount left over is insufficient space for a plant, but can be considered as additional area for the border. Also, there are different shapes of fields and even rectangular figures of varied dimensions for which Rule 12 may not exactly give the correct number of plants. However, Rule 12 will result in an answer of sufficient reliability.

Many crops are not planted in checked rows, but in drills. The rows are maintained in only one direction, and in each row the plants are spaced at fairly regular smaller intervals. Because of the likelihood of slight irregularities in planting the seed, you cannot be sure that each plant will be at the corner of a rectangle. However, you can still get a fairly close result with Rule 12 by using the distance between the rows and the distance between the plants along the row as the base and height of the rectangle, respectively.

Example I. When sweet corn is planted in hills, 3 feet apart each way, and averages 3 stalks to the hill, how many plants are there to the acre?

- (a) For each hill, the area = $3' \times 3'$, or 9 sq. ft.
- (b) No. of hills per acre = $43,560 \div 9 = 4840$ hills.
- (c) $4840 \text{ hills} \times 3 \text{ stalks per hill} = 14,520 \text{ plants}$.

Example II. Field corn in checked rows is usually planted in hills 44" apart each way. When yielding 3 stalks to the hill, how many plants are there to the acre?

- (a) For each hill, the area is $44'' \times 44''$.

$$44'' = 3\frac{2}{3}'. \quad 3\frac{2}{3}' \times 3\frac{2}{3}' = \frac{121}{9} \text{ sq. ft.}$$

(b) $43,560 \div \frac{121}{9} = 3240$ hills per acre.

(c) $3240 \text{ hills} \times 3 \text{ stalks per hill} = 9720 \text{ plants.}$

Example III. When peanuts are planted in rows 3' apart, and 9" apart along the row, how many plants are there per A?

(a) For each plant, the area = $3' \times \frac{3}{4}'$, or $\frac{9}{4}$ sq. ft.

(b) $43,560 \div \frac{9}{4} = 19,360 \text{ plants.}$

Practice in Finding the Number of Plants Per Acre.

1. Find the number of plants per acre for the following crops in checked rows:

(a) Squash bush, in rows 4' apart each way;

(b) Watermelon, in rows 8' apart each way;

(c) Tomato, in rows $2\frac{1}{2}'$ apart each way.

2. Find the number of plants per acre for the following crops in drills:

(a) Sweet Potato, every 1' along rows 3' apart;

(b) Potato, every 18" along rows 3' apart;

(c) Cabbage, every 20" along rows $2\frac{1}{2}'$ apart.

3. A farmer planted dent corn in checked rows, 42" apart each way. If he obtained an average stand of two stalks to the hill, what was the number of plants in an acre?

4. In cotton spacing experiments in Alabama, best results were obtained in rows $3\frac{1}{2}$ feet apart, with hills 18 inches apart in the rows. What is the number of plants per acre, if thinned down to two plants to the hill?

5. In Florida, bright tobacco plants are set in rows 4 ft. apart, with the plants from 20 in. to 26 in. apart in the row. How many plants can be set on an acre of land, when spaced 20" apart along the row?

6. How many orange trees can be planted in an acre of nursery rows, $3\frac{1}{2}$ ft. apart, with the trees spaced 12" apart?

7. How many sugar beet plants are there in an acre, after thinned down to one plant every 8", if the rows are 28" apart?

Find the Amount of Seed Needed to Plant a Crop.**QUANTITY OF SEED FOR SOME FARM GARDEN
VEGETABLES**

<i>Crop</i>	<i>Plants spaced in the row</i>	<i>Seed required for 100 feet of row</i>
Asparagus	18 in.	$\frac{1}{2}$ ounce
Cucumber	3 ft.	1 packet
Lima bean	3 to 4 in.	1 pint
Potato	14 in.	$5\frac{1}{2}$ pounds
Radish	1 in.	1 ounce

1. How much radish seed is needed to plant four 125' rows?
2. How much potato seed is needed for three 150' rows?
3. How much asparagus seed is needed for six 75' rows?
4. How much lima bean seed is needed for eight 45' rows?
5. Find the total amount of cucumber seed required for five 65' rows and seven 82' rows.
6. Find the amounts of each kind of seed needed to plant $12\frac{1}{2}$ acres with the following Tennessee hay and pasture mixture for limed land: Alfalfa—10 lb., Orchard grass—8 lb., Ky. bluegrass—4 lb., and White clover— $1\frac{1}{2}$ lb. per acre.
7. How much seed must be used to plant a silage crop of $21\frac{1}{4}$ acres with the following mixture: 8 lb. of corn, 3 lb. of sorghum, and 15 lb. of cowpeas, per acre?
8. Shelled Spanish peanut seed number from 1000 to 1500 to a pound. When a variety counting about 1200 to a pound is used, how many pounds of seed are needed to plant one acre in rows 24" apart, if the seeds are dropped every 4"?
9. If about $\frac{1}{2}$ teaspoonful is the proper amount of tobacco seed for 100 square feet of bed, how many ounces are needed for 4800 square feet of bed (1 ounce of tobacco seed = about 12 teaspoonsful)?
10. The general rule is to plant 200 square feet of tobacco bed for each acre of land to be set from the bed. About how much land can be planted from 2450 sq. ft. of tobacco bed?
11. How many acres of bright tobacco can be planted from 1350 sq. ft. of tobacco bed, at 50 sq. yd. of bed per acre?

PLANTING ARRANGEMENTS OF ORCHARDS

I. The Square System.

This system is the most commonly used. Each tree is set at the corner of a square, so that all trees in the orchard are the same distance from one another. This provides every tree with the proper amount of soil for the spread of roots, and enough space is supplied for the extension of branches. Also, the plan gives easier access to the land and the trees for cultivation, spraying and harvesting.



A Profitable Pear Orchard, Planted in the Square System.

Distance for Planting.

The proper amount of space between the trees depends on the kind of fruit, even in many cases its variety, and the fertility of the soil. Obviously, crowding will interfere with the growth of the trees, and may produce a smaller yield of fruit. However, closer spacing may produce a greater total yield per

acre. Wide spacing may be necessary because of poor soil, or as an aid to spraying and cultivation.

The exact number of feet cannot be specified for spacing different trees, because of these varying conditions. For example, a distance of 50 to 60 feet is recommended for walnut trees, where no thinning is contemplated. The table arranged below gives the range of safe distances for planting fruit trees. The fruit grower should decide the exact distance himself, according to conditions on his own farm.

USUAL SPACING FOR ORCHARDS

<i>Fruit</i>	<i>Distance between trees</i>
Apple	30 to 40 feet
Apricot	16 to 25 feet
Sour Cherries	16 to 20 feet
Sweet Cherries	25 to 30 feet
Peaches	16 to 25 feet
Pears	16 to 25 feet
Plums	16 to 25 feet
Quince	10 to 15 feet

Number of Trees Per Acre.

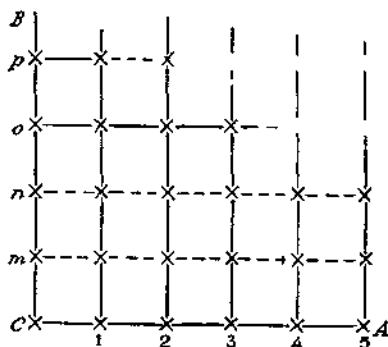
Use the same method of calculation as for finding the number of plants per acre. Each tree occupies one square space, whose area is the square of the desired planting distance. For the number of trees per acre, divide 43,560 sq. ft. by the number of square feet in the square taken by one tree. In actual practice, less than this calculated number of trees may fit into an acre, on account of the shape of the planting area. For a large number of acres, the variation from the calculated result will at most be slight.

Practice in Finding the Number of Trees Per Acre.

- Find the number of trees per acre for the following fruit trees planted in the square system:
 - Apple trees, 40 feet apart;
 - Peach trees, 20 feet apart;
 - Pear trees, 25 feet apart;

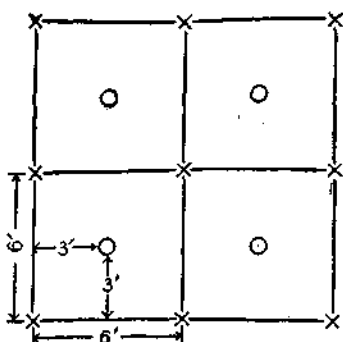
- (d) Quince trees, 12 feet apart;
 - (e) Sweet cherry trees, 30 feet apart;
 - (f) Plum trees, 24 feet apart.
2. How many walnut trees can be planted per acre, spaced 55 feet apart in the square system?
 3. How many plants are required to set 1 acre with Muench variety grape vines, spaced 10' apart each way?
 4. If the proper spacing for Christmas Trees is 4 by 4 ft., in the square system, find the number of trees per acre.

Laying out the orchard. Sight a base-line CA along one side of the field, where the first row of trees will be set. Mark the positions of the trees along this line by placing stakes at regular intervals. Use the desired distance between the trees as the length of each interval. Sight a second base line CB at right angles with CA, for the first row of trees along the length of the field. Set stakes at positions m, n, o, etc., along the line CB at the same regular intervals. In the same way, mark the positions of the trees successively along lines perpendicular to CA, from the stakes 1, 2, 3, etc. Check the regularity of spacing occasionally by sighting across from positions, m, n, o, etc.



II. The Quincunx System.

The quincunx system is the same as the square system, except that an additional tree is planted at the center of each square. This method is rarely used as a permanent plan for an orchard. The center trees, called fillers, are temporary trees which provide a crop before the orchard would otherwise be profitable. Fillers should be removed before they crowd the roots or branches of the permanent trees.



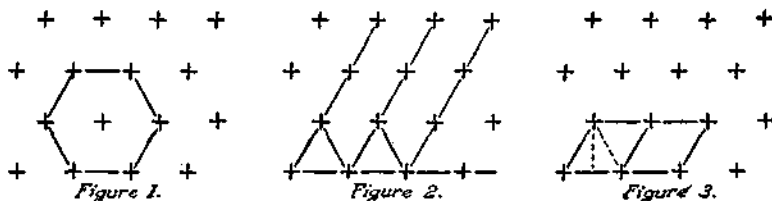
The United States Department of Agriculture suggests this system for the production of timber and Christmas trees on the same plot. Pine trees for timber production can be planted 6' x 6' by square spacing (X = timber tree), and Christmas trees can be grown as fillers (O = Christmas tree). When the Christmas tree crop is removed, the timber plan-

tation remains, properly spaced.

The quincunx system provides space for the usual number of trees in a square system, and in addition, a filler crop of about 75% as many trees as the square system.

III. The Hexagonal System.

In this arrangement, a tree is set at each corner and at the center of a regular hexagon (Fig. 1). As appears in Fig. 2, each tree is also at a vertex of an equilateral triangle. Therefore, the system is also called the **triangular or equilateral triangle system**. Each tree is the same distance from every other tree, as in the square system. Moreover, more trees per acre can be planted by the hexagonal system.



Laying out the orchard. Sight one base-line, and set stakes at the regular intervals for the planting of the trees. Sight the rows at an angle of 60° from the base-line, and mark the positions of the trees along the rows at the same regular intervals. (See Fig. 2).

The field can be laid out without the use of a transit or

other instrument for sighting the 60° angle. Suppose the field will be used for apple trees, to be set 40 feet apart. Use two lengths of wire, each 40' long, joined by a small ring, and having a larger ring attached at the free end of each wire. Place the free rings over the first two stakes on the base-line. Stretch the wires tightly, and mark the position of a tree at the small ring. Then place the rings over the 2nd and 3rd stake, pull the wires taut, and mark the position of another tree. Repeat this throughout the field, and check occasionally to keep the rows straight.

Space for each tree. Figure 3 shows that the space for each tree is the area of a parallelogram. Its base is the distance between the trees, and its height is the altitude of the equilateral triangle.

Finding the Number of Plants Per Acre in the Hexagonal System.

The length of the altitude of the parallelogram for each tree equals $\sqrt{3}/2$ times the distance for spacing the trees, or about .866 times the distance (See page 120). Since the rows are closer together in this direction, more space per acre is available for the planting of trees. There is about 1.155 times as much space per acre in this way. An approximate method for finding the number of trees per acre in the hexagonal system is: **Divide 50,297 sq. ft. by the number of square feet in the square of the distance between the trees.**

Problems in the Hexagonal and Quincunx Systems.*

1. Find the approximate number of trees per acre for the following fruit trees planted in the hexagonal system. Use the formula: $50,297 \div d^2$.

- (a) Christmas trees, 3 feet apart;
- (b) Sour cherry trees, 20 feet apart;
- (c) Apple trees, 40' apart (See prob. 1a, page 52);

* A table on page 282 in the appendix gives the theoretic number of trees per acre, according to the three systems.

- (d) Plum trees, 24' apart (See prob. 1f, page 53).
2. Find the approximate number of fillers per acre for the following trees (quincunx system):
- Method: (1) Find the no. of trees in the square system.
 (2) The no. of fillers is about $\frac{3}{4}$ this amount.
- (a) Christmas tree fillers for timber spaced 8' apart;
 (b) Plum tree fillers for apple trees spaced 35' apart;
 (c) Peach tree fillers for apple trees spaced 36' apart;
 (d) Peach tree fillers for apple trees spaced 38' apart.

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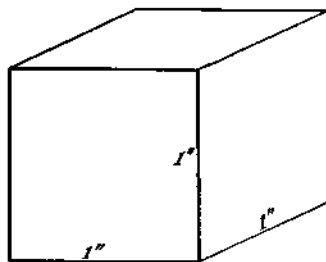
Chapter VI

MEASUREMENT OF VOLUME

LENGTH has one dimension; surface has two dimensions; and there are figures that have three dimensions. A **solid** is a figure that has three dimensions: length, width and height. When we find the contents of a solid or the amount of space it occupies, we are measuring its *volume*. It is important to measure the volumes of many solids about a farm, such as silos, water tanks, bins, loads of hay, piles of grain, and cases and baskets for farm products. The existence of the pyramids in Egypt shows that man was familiar with the measurement of volume for thousands of years back.

Just as we needed units of length and of area, we must have a unit for the measurement of volume. The usual unit of volume is **1 cubic inch**. A cubic inch is a solid which measures 1 inch in length, 1 inch in width and 1 inch in height.

The bounding surfaces of a solid are called its **faces**. Each face of the cubic inch is a square having an area of 1 square inch.



Other units for the measurement of volume are 1 cubic foot and 1 cubic yard. A box 1 ft. long, 1 ft. wide and 1 ft. high (all inside dimensions), holds 1 cubic foot. We could fit 12 cubic inches along the length and 12 cubic inches along the width, or a total of 144 cubic inches in 1 layer at the bottom of the box. As the height is also 1 foot, 12 such layers would fit into the box, making 1728 cubic inches in 1 cubic foot. In the same way, 1 cubic yard contains 27 cubic feet (3 feet in 1

yard). Convenience is your guide in the selection of the particular unit, according to the size of the volume to be measured.

Cubic Measure

$$1728 \text{ cu. in.} = 1 \text{ cu. ft.}$$

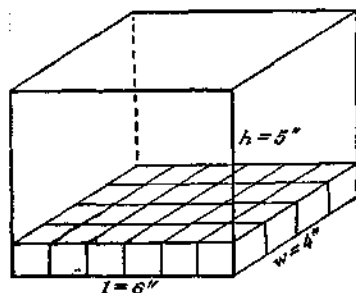
$$27 \text{ cu. ft.} = 1 \text{ cu. yd.}$$

Practice in Conversion of Measurements of Volume.

1. Change 8 cu. ft. to cu. in.; 12 cu. yd. to cu. ft.
2. Change 10 cu. ft. to cu. in.; 8 cu. yd. to cu. ft.
3. Change 3 cu. yd. to cu. in.
4. Change 7 cu. yd. to cu. in.
5. Change 6912 cu. in. to cu. ft.; 594 cu. ft. to cu. yd.
6. Change 3456 cu. in. to cu. ft.; 864 cu. ft. to cu. yd.
7. What part of a cu. ft. is 216 cu. in.; 108 cu. in.?
8. What part of a cu. yd. is 3 cu. ft.; 9 cu. ft.?

Finding the Volume of a Rectangular Solid.

The rectangular solid has straight lines for edges, and rectangles for faces. Bins, cribs and boxes are usually rectangular



solids. How can we measure the volume of a rectangular solid, that is, determine the number of cubic units it contains?

The dimensions of the rectangular solid at the left are: length = 6 in., width = 4 in., and height = 5 in. Six rows of cubic inches, four cubic inches in a row, or $6 \times 4 = 24$ cubic inches, would fit on the bottom of the solid. Five layers make a total of $6 \times 4 \times 5$, or 120 cu. in., the volume of the solid.

You can find the volume of any rectangular solid without actually counting the number of cubic units that would fit into the solid. The length, width and height indicate the number of rows of cubic units, the number in a row and the

number of layers. To calculate the volume, measure the number of linear units in the length, width and height; then multiply these three dimensions together.

RULE 13. The volume of a rectangular solid equals the product of the length by the width by the height.

FORMULA: $V = l w h$

**Practice in Computing the Volumes
of Rectangular Solids.**

1. What is the number of cubic feet in a bin 12' long, 8' 3" wide and 5' 2" high?

**SAMPLE
METHOD**

$$\begin{aligned} l &= 12' & V &= l w h \\ w &= 8\frac{1}{4}' & V &= \frac{12}{1} \times \frac{33}{4} \times \frac{31}{6} \\ h &= 5\frac{1}{6}' & & \\ \text{Answer: } V &= 511\frac{1}{2} \text{ cu. ft.} \end{aligned}$$

2. Find the volumes in cubic feet of bins of the following dimensions:

- (a) $l = 11 \text{ ft.}, w = 8 \text{ ft.}, h = 5 \text{ ft.};$
 (b) $l = 25 \text{ ft.}, w = 20 \text{ ft.}, h = 8 \text{ ft.};$
 (c) $l = 12 \text{ ft.}, w = 8 \text{ ft. } 6 \text{ in.}, h = 7 \text{ ft. } 4 \text{ in.};$
 (d) $l = 18 \text{ ft.}, w = 12 \text{ ft. } 8 \text{ in.}, h = 9 \text{ ft. } 2 \text{ in.}$

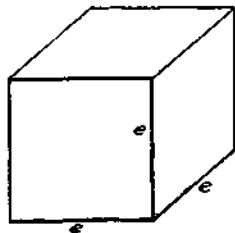
3. Find the number of cubic feet in the following cribs:

- (a) $24' \times 22' \times 10'$ (c) $15' \times 9' 4'' \times 9'$
 (b) $21' \times 18' \times 9'$ (d) $22' \times 14' 6'' \times 8' 3''.$

Finding the Volume of a Cube.

A cube is a special kind of rectangular solid: its length, width and height are equal to each other. Thus, all of the edges are equal.

If we use the formula $V = l w h$ to find the volume of a cubic block, each edge of which is 4", we get $V = 4 \times 4 \times 4 = 64$ cu. in. In the same way, if the edge is 5", then $V = 5 \times 5 \times 5 = 125$ cu. in.



Represent the edge of any cube by the letter e . Then $V = e \times e \times e$ is a formula for the volume of any cube. This can be reduced to mathematical shorthand by using a base e and an exponent ³.

RULE 14. The volume of a cube equals the cube of its edge.

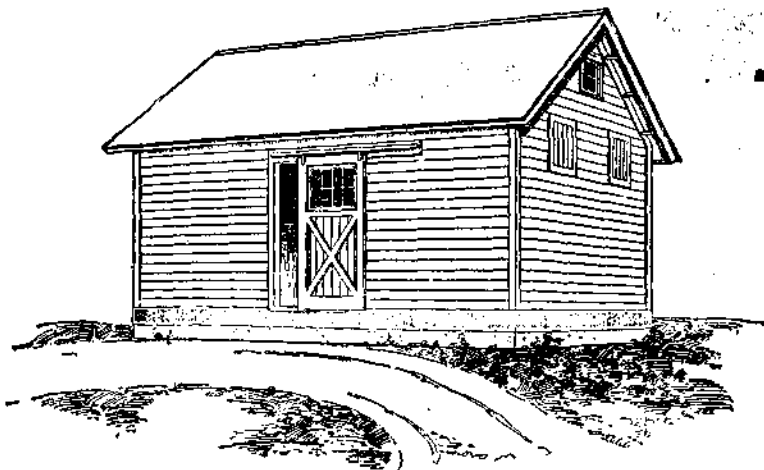
FORMULA: $V = e^3$ (This reads: "V equals e cube").

1. Find the volumes of the following cubical bins:

- | | | |
|------------------|----------------------------|-----------------------|
| (a) $e = 10$ ft. | (c) $e = 7\frac{1}{2}$ ft. | (e) $e = 9$ ft. 4 in. |
| (b) $e = 12$ ft. | (d) $e = 8.4$ ft. | (f) $e = 8$ ft. 3 in. |

The Capacity of a Bin or Crib in Bushels.

I. The standard bushel of grain occupies 2150.42 cu. in. Dividing 1728 (the number of cubic inches in 1 cubic foot) by 2150.42, the quotient is approximately .8. For ordinary practical calculations, we may say that 1 cubic foot contains .8 of a bushel of grain. Dividing 2150.42 by 1728, the quotient is approximately 1.25. For ordinary practical purposes, we may say that 1 bushel of grain occupies approximately 1.25 cubic feet.



A Granary 14 by 24 Feet, with Four Bins Each of 450 Bushels Capacity.
Courtesy of the United States Department of Agriculture.

II. One heaped bushel (used for potatoes, apples, ear corn, etc.) occupies 2747.71 cu. in. Dividing in the same way as in I above, we find that for practical purposes we may say that 1 cubic foot contains .63 heaped bushels, and that 1 heaped bushel occupies 1.6 cubic feet.

III. For practical purposes, we consider that 1 cubic foot of ear corn in a crib contains .4 bushels of shelled corn, and that 1 bushel of shelled corn is supplied by ear corn occupying 2.5 cubic feet.

RULE 15. To find the approximate number of bushels of farm products in bins and cribs:

- (a) The number of bushels of grain in a bin = the number of cubic feet in the bin $\times .8$ (or $4/5$).
- (b) The number of heaped bushels of potatoes, apples, ear corn, etc., in a bin = the number of cubic feet in the bin $\times .63$.
- (c) The number of bushels of shelled corn in a crib of ear corn = the number of cubic feet in the crib $\times .4$ (or $2/5$).

Find the number of bushels of grain in the following bins:

1. $8' \times 8' \times 5'$
2. $10' \times 10' \times 10'$
3. $12' \times 8' \times 7\frac{1}{2}'$
4. $10' \times 8\frac{1}{4}' \times 7\frac{1}{3}'$

Find the number of heaped bushels in the following bins:

5. $8' \times 8' \times 10'$
6. $12' \times 16' \times 8'$
7. $14' \times 10' \times 6\frac{3}{4}'$
8. $18' \times 12\frac{1}{2}' \times 7\frac{1}{3}'$

Find the number of bushels of shelled corn in the following cribs of ear corn:

9. $20' \times 6' \times 7\frac{1}{2}'$
10. $12' \times 18' \times 8\frac{1}{4}'$

11. A wagon box is 12 ft. long, 4 ft. wide and 30 in. high. What is the value of a full load of wheat at 72¢ per bushel?

12. What is the weight of a full truck load of oats, if the box is 10 ft. long, 6 ft. wide and 40 in. high? (1 bu. of oats weighs 32 lb.) *

13. A crib of ear corn is $16\frac{2}{3}$ ft. long, 12 ft. wide and $8\frac{1}{2}$

* See table of weights of commodities, in the appendix, page 280.

ft. high. How much is a full crib of ear corn worth, at 54¢ per bushel of shelled corn?

14. The inside dimensions of a box car carrying wheat are 52 ft. by $8\frac{1}{2}$ ft. When the grain in the car is about $5\frac{1}{2}$ ft. deep, what is it worth at 68¢ per bushel?

15. A bin 14 ft. x $8\frac{1}{2}$ ft. x 8 ft. is $\frac{3}{4}$ full of barley. If the grain was sold for 56¢ per bushel, what was the total price?

General Problems in Volumes of Rectangular Solids.

The space required for a ton of coal varies according to the type and size of coal. A fair estimate for hard coal is 36 cubic feet per ton, and for soft coal, 40 cubic feet per ton.

1. A coal bin is 12' x 8' x 5'. Find the number of tons of hard coal it can hold; the number of tons of soft coal.

Suggestion: Use the cancellation method.

2. A coal bin $10\frac{1}{2}$ ft. x $7\frac{1}{3}$ ft. is filled with hard coal to a height of 6 ft. What is the value of the coal at \$11 per ton?

3. Find the cost of soft coal that will fill a bin 12 ft. x $9\frac{1}{2}$ ft. x $4\frac{1}{2}$ ft., if \$8.20 is the charge per ton.

4. A coal bin is 15' x 20'. To what height would 30 tons of soft coal reach in the bin?

Suggestion: Divide the total number of cubic feet required for the coal by the area of the bin.

The weight of ice is approximately 57 lb. per cubic ft.

5. A farmer cuts ice 16 in. thick from an ice field. Find the weight of a block of ice 4 ft. x 2 ft.

6. Find the weight of a cut of ice 5 ft. x $1\frac{1}{2}$ ft. x 12 in.

7. An ice field has ice 14 inches thick.

(a) How many cu. ft. are there in an acre of this ice?

(b) Assuming that the waste in cutting the ice is balanced by the waste of space in packing, how high would this quantity of ice fill an ice house 80' x 40' (inside dimensions)?

Construction.

8. How many cubic yards of dirt must be removed to dig a cellar 8 feet deep for a house 24' x 54'?

Suggestion: Use cancellation; 27 cu. ft. = 1 cu. yd.

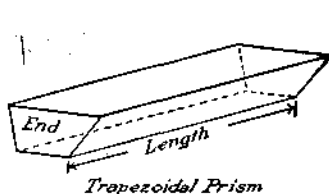
9. If the capacity of a truck is 2 cubic yards, how many full loads of dirt must be removed for an excavation 45' x 24' x 9'?

10. How many cubic yards of concrete are needed for the floor of a poultry house, 4" thick, and measuring 20' x 24'?

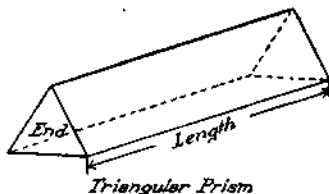
11. A farmer builds a square grain bin 14' x 14'. How many cubic yards of concrete are needed for a 6" floor?

Finding the Capacities of Trench Silos and other Prisms.

The ends of a right prism are equal, parallel polygons,* and the sides are rectangles. The rectangular solid is a rectangular prism; the trench silo is a trapezoidal prism; and the attic of a house may be a triangular prism.



Trapezoidal Prism



Triangular Prism

RULE 16. The volume of a right prism equals the product of the area of an end (base) by the length (height).

FORMULA: $V = Bh$

Weight of silage in a trench silo. The weight of 1 cubic foot of silage depends upon the type of crop, the maturity of the crop when packed in the silo, how tightly the silage has been packed, the depth of the trench, and possibly some other factors. For average trench silos, the weight of silage may vary between 25 and 35 pounds per cubic foot. As 1 ton equals 2000 lb., take 65 cu. ft. for 1 ton of silage. We will consider silage again in connection with cylindrical silos, and in the study of feeding farm animals.

* A polygon is a figure bounded by straight lines. Triangles, quadrilaterals, hexagons, etc., are polygons.

Computing the Capacities of Trench Silos.

1. How many tons of silage can be stored in a trench silo 7 ft. deep, 8 ft. wide across the top and 6 ft. wide across the bottom, and 46 ft. long?

(1) Area of trapezoid = 49 sq. ft. (Pages 31, 32)

METHOD (2) $B = 49$ sq. ft. $V = Bh$
 $h = 46$ ft. $V = 49 \times 46 =$
 2254 cu. ft.

(3) $2254 \div 65 = 34.7$ tons (to the nearest tenth)

2. Find the capacities in tons of the following silos:

	Width at top	Width at bottom	Depth of trench	Length
(a)	7 ft.	5 ft.	6 ft.	39 ft.
(b)	12 ft.	8 ft.	7 ft.	60 ft.
(c)	13 ft.	9 ft.	8 ft.	38 ft.

Capacities of Prism-Shaped Bins, etc.

3. Find the number of bushels of ear corn in a full crib 20 ft. long, 8 ft. wide, 8 ft. high at the back and 6 ft. high at the front. (Prism with trapezoidal base).

4. Find the number of bushels of apples in a full bin 18 ft. long, 12 ft. wide, 6 ft. high on one side and 10 ft. high on the other side.

5. The body of a truck carrying oats measures 8 ft. long and 4 ft. high, and has slanting sides. The width at the bottom is 4 ft. and the width at the top is 6 ft. How many bushels are there in a full load of oats? (Prism with trapezoidal base).

6. How many bushels of wheat can be carried in a truck, if the receptacle is 10 ft. long, 5 ft. high, 5 ft. wide at the bottom and 7 ft. wide at the top?

Measurement of Cordwood.

Wood used as fuel is measured in cords. One cord is the amount of wood contained in a pile 8' long, 4' wide and 4' high. The quantity of piled wood in the cord is 128 cu. ft. A pile of 2-foot wood is also 1 cord if the pile is 8 ft. long and

8 ft. wide, because $2 \times 8 \times 8 = 128$ cu. ft. In the same way, other dimensions may be possible to make up 1 cord of wood.

Find the number of cords in the following piles of wood:

1. $20' \times 8' \times 4'$.

Suggestion: Use cancelation.

2. $64' \times 10' \times 4'$.

1. $\frac{20 \times 8 \times 4}{8 \times 4 \times 4}$

3. $80' \times 10' \times 4'$.

$\frac{20 \times 8 \times 4}{8 \times 4 \times 4}$

4. $60' \times 8' \times 6'$.

5. $50' \times 8' \times 6'$.

6. Find the cost of a pile of cordwood 8 ft. high, 4 ft. wide, 26 ft. long at the bottom and 22 ft. long at the top, at \$4 per cord.

7. What is the cost of a pile of cordwood 6 ft. high, 4 ft. wide, 38 ft. long at the top and 42 ft. long at the bottom, at \$4.20 per cord?

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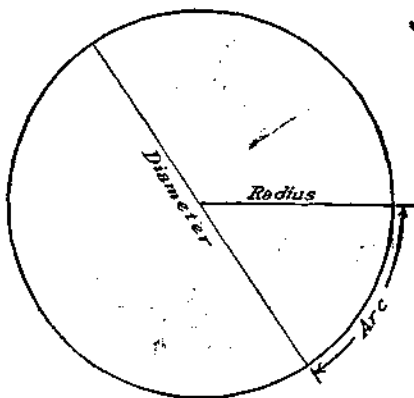
Chapter VII

MEASUREMENT OF CIRCULAR AND CYLINDRICAL OBJECTS

The Circle.

In the course of your work on the farm, you will often find it necessary to measure circles. Silos, tanks, wheels, and other objects, require circular measurement.

Draw a circle with your compasses. The point from which the circle is drawn is called the **center**. The curved line which bounds the circle is the **circumference**. The **radius** is the distance from the center to any point on the circumference. An **arc** is a portion of the circumference.



Draw a straight line through the center of the circle, both ends reaching the circumference. This line is a **diameter**. The radius of the circle at the right is 1 inch long, and the diameter is 2 inches.

Some important facts about the circle are:

- (1) All radii of the same circle are equal;
- (2) The radius equals one-half the diameter, $r = \frac{d}{2}$;
- (3) All diameters of the same circle are equal;
- (4) The diameter equals twice the radius, $d = 2r$.

Answer these questions without using pencil and paper.

1. What is the diameter of each circle, having the following radii?

- | | | |
|------------|------------------------|--------------|
| (a) 5 ft. | (c) 4 ft. 5 in. | (e) 3.7 in. |
| (b) 10 in. | (d) $8\frac{1}{4}$ ft. | (f) 15.5 ft. |

2. What is the radius of each circle, having the following diameters?

- | | | |
|------------|-------------------------|--------------|
| (a) 6 in. | (c) 6 ft. 8 in. | (e) 8.4 in. |
| (b) 15 ft. | (d) $14\frac{1}{2}$ ft. | (f) 12.5 ft. |

Finding the Length of the Circumference.

The direct measurement of the circumference of a circle is usually inconvenient and inaccurate. How can you find its length through the direct measurement of some straight line in the circle?

Experiment to find the relationship between the circumference and the diameter of any circle:

(1) Use the stump of a tree, the bottom of a pail, the face of a half-dollar, or any circular object.

(2) Carefully measure the distance around the object (the circumference), and also the diameter of the object. The circumference of a small object can be measured by rolling it along a straight line and marking the length of the circumference along this line.

(3) Divide the length of the circumference of each circle by its diameter. Is each quotient slightly more than 3?

(4) You have found that the ratio of the circumference to the diameter of any circle is approximately $3\frac{1}{7}$.

The ancient Egyptians and Babylonians knew that the ratio of the circumference to the diameter is the same for all circles. However, they did not know a very close approximation of the value of this ratio. Mathematicians have attempted to find the exact value of this ratio, without success. The ratio has been worked out to hundreds of places, but the last place is never exact. In fact, mathematicians finally proved that the exact value of the ratio cannot be found. As the ratio cannot

be expressed as an exact decimal or fraction, it is usually represented by the Greek letter π (pi).

$\pi = 3.141592653589793238462643383279$, nearly.
(30 places). Calculations with this value would be very cumbersome, and still not exact. For usual calculations in agriculture, use

$$\pi = 3.14 \quad \text{or} \quad \pi = 2\frac{2}{7} \quad (3\frac{1}{7}).$$

We know that the ratio of the circumference of any circle to its diameter is π . Therefore, to find the length of the circumference of a circle, measure the diameter and then multiply by the value of π .

RULE 17. The length of the circumference of any circle equals the value of π times the diameter.

FORMULA: $C = \pi d$ or $C = 2\pi r$.

Practice in Computing the Circumference of a Circle

1. If the diameter of a wheel is 28 in., what distance will it move horizontally in one revolution (circumference)?

SAMPLE PLAN	$C = \pi d$	Cancel:
and	$d = 28 \text{ in.}$	$C = 2\frac{2}{7} \times 28$
METHOD	$\pi = 2\frac{2}{7}$	$C = 88 \text{ in. or } 7'4'' \frac{22}{7} \times \frac{28}{1}$

2. What is the distance around the edge of a pulley, having a 4 inch radius?

SAMPLE PLAN	$C = 2\pi r$	Multiply:
and	$r = 4 \text{ in.}$	$C = 2 \times 3.14 \times 4$
METHOD	$\pi = 3.14$	$C = 25.12 \text{ in.}$ <i>Answer</i>

3. Find the circumferences of the following circles:

- | | |
|--------------------------|-------------------------------------|
| (a) $d = 14 \text{ ft.}$ | (e) $r = 8 \text{ ft.}$ |
| (b) $d = 3 \text{ in.}$ | (f) $r = 10\frac{1}{2} \text{ in.}$ |
| (c) $d = 15 \text{ ft.}$ | (g) $r = 5 \text{ in.}$ |
| (d) $d = 7 \text{ in.}$ | (h) $r = 35 \text{ ft.}$ |

4. What must be the length of a steel cable, to reach around a circular silo having a 26 foot diameter?

5. The radius of a circular flowerbed is 7 ft. How many flowers can be placed around the edge, when spaced one foot apart along the circumference?

RULE 18. The length of the diameter of any circle equals the circumference divided by the value of π .

FORMULA:
$$d = \frac{C}{\pi}$$

6. What is the diameter of a wheel, if the circumference equals 110 inches? (Use $\pi = 2\frac{2}{7}$).

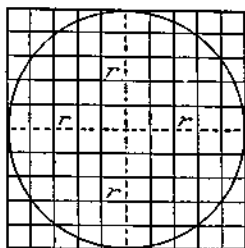
7. The distance around a tree is 42 feet. Find its diameter.

8. Taking the approximate circumference of the earth at the equator as 25,000 miles, find its radius.

Finding the Area of a Circle.

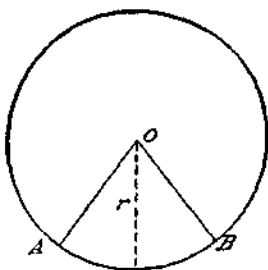
Draw on squared paper a circle having a radius of 5 units. What is the area of the circle? Can you count the exact number of square units in the circle?

Draw a square touching this circle at four points (The square is said to be circumscribed about the circle). Then the area of each small square equals r^2 , or 25 square units. The entire square has an area of $4r^2$, or $4 \times 25 = 100$ square units. The area of the circle is less than the area of the large square, and hence less than 100 square units. If you make an actual count of the number of square units in the circle, estimating fractions of squares, you will find that the area of the circle is a little more than three times the square of the radius. In more advanced mathematics, it is proved that this number of times r^2 is the same number π that is used in calculating the circumference of a circle.



RULE 19. The area of a circle equals the value of π times the square of the radius.

FORMULA:
$$A = \pi r^2$$



This formula for the area of a circle can be shown in another way. Assume sector OAB of the circle to be a triangle. To find its area, we would use the formula $A = \frac{1}{2}bh$; the altitude equals r and the base is the arc AB. Considering the entire circle to be such a triangle, r is still the altitude, but the base is the whole circumference. There-

fore, by use of the formula $A = \frac{1}{2}bh$, we find the following:

(1) $A = \frac{1}{2}rC$ (sometimes used as a formula for area).

(2) $C = 2\pi r$. Therefore, $A = \frac{r \times 2\pi r}{2} = \pi r^2$

Practice in Computing the Areas of Circles.

1. Over what area can a cow graze, when tied to a rope 28 feet long?

SAMPLE METHOD $r = 28$ ft. $A = \pi r^2$ Cancel:*
 $\pi = 2\frac{3}{4}$ $A = 2\frac{3}{4} \times 28 \times 28$ $\frac{22}{7} \times \frac{28}{1} \times \frac{28}{1}$
 $A = 2464$ sq. ft.

2. What is the area of the end of a piston head having a 3 inch diameter?

SAMPLE PLAN $d = 3$ in. $A = \pi r^2$
 and $r = 1.5$ in. $A = 3.14 \times 1.5 \times 1.5$
METHOD $\pi = 3.14$ $A = 7.065$ sq. in. *Answer.*

3. Find the areas of the following circles:

- | | |
|------------------|------------------|
| (a) $r = 6$ in. | (e) $d = 28$ ft. |
| (b) $r = 7$ ft. | (f) $d = 10$ in. |
| (c) $r = 25$ ft. | (g) $d = 5$ in. |
| (d) $r = 21$ ft. | (h) $d = 23$ ft. |

4. What is the area of the cross section of a water pipe, if its radius is 2 inches?

* 5. Work out Special Drill number 6, on page 272 in cancellation.

6. What is the area of a circular sheet of iron having a 7 inch radius?

7. Over what area can a horse graze, if tethered to a 50 foot rope?

8. An open top circular tank has a 12 foot diameter. If canvas is used over the opening, how much area must be covered by the canvas?

9. A giant redwood tree has a diameter of 30 feet.

(a) What is its circumference?

(b) What is the area of the stump, if the tree is cut off so that the top of the stump is level?

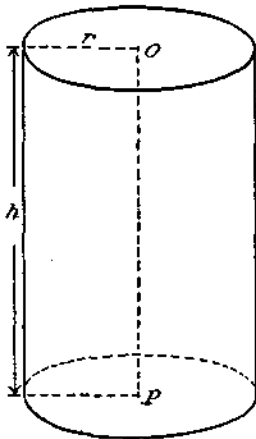
10. One circle has a diameter of 7 ft. Another circle has a diameter of 14 ft. Find the area of each. Complete this sentence: If the diameter of one circle is 2 times the diameter of a second circle, the area of the first circle is — times the area of the second.

11. Compare the areas of two circles, having diameters of 6 in. and 18 in. respectively.

Finding the Volume of a Cylinder.

The bases of a circular cylinder are two equal and parallel circles. A uniformly curved surface joins these two circles. The height of the cylinder is the perpendicular distance between the bases (line OP). Some objects that are usually cylindrical in shape are silos, water tanks, wells, water pipes, and tin cans.

If we compute the area of the base of a cylinder, we find the number of cubic units that fit on the base. The number of linear units in the height indicates the number of such layers of cubic units in the entire cylinder. For the complete volume, we must multiply the amount in one layer by the number of layers. The formula for the area of



a circle is: $A = \pi r^2$. Therefore, in finding the volume of a cylinder, we use πr^2 for the base of the cylinder. Use "h" for the height.

RULE 20. The volume of a cylinder equals the product of the area of the base by the height.

FORMULA: $V = \pi r^2 h$

Example I. What is the volume of a cylindrical water tank having a depth of 8 ft. and a radius of 3 ft.?

SAMPLE PLAN	$r = 3 \text{ ft.}$	$V = \pi r^2 h$
and	$h = 8 \text{ ft.}$	$V = 3.14 \times 3 \times 3 \times 8$
METHOD	$\pi = 3.14$	$V = 226.08 \text{ cu. ft. Answer}$

Example II. Find the number of cubic feet of silage in a silo, if the silage is 21 ft. deep and the silo is 12 ft. in inside diameter.

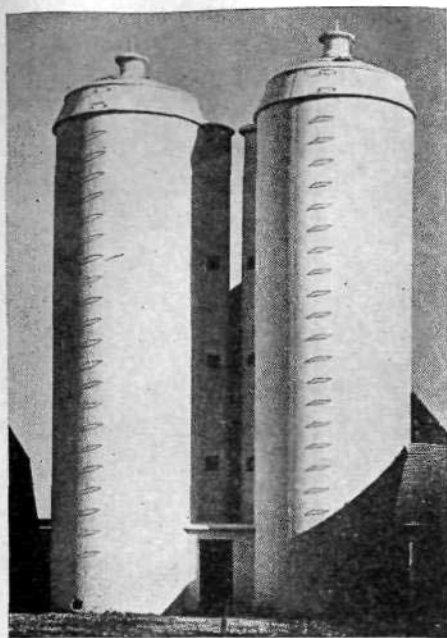
SAMPLE PLAN	$V = \pi r^2 h$
and	
METHOD	$V = \frac{22}{7} \times \frac{6}{1} \times \frac{6}{1} \times \frac{21}{1}$
$d = 12 \text{ ft.}$	$V = 2376 \text{ cu. ft. Answer.}$
$r = 6 \text{ ft.}$	Note: Use the cancellation
$h = 21 \text{ ft.}$	method.
$\pi = \frac{22}{7}$	

Practice in Computing the Volumes of Cylinders.

- Find the volumes of the following cylinders:
 - $r = 5 \text{ ft.}, h = 12 \text{ ft.}$
 - $r = 7 \text{ ft.}, h = 14 \text{ ft.}$
 - $r = 4 \text{ in.}, h = 30 \text{ ft.}$
 - $r = 3 \text{ in.}, h = 35 \text{ ft.}$
 - $d = 20 \text{ ft.}, h = 35 \text{ ft.}$
 - $d = 6 \text{ in.}, h = 4 \text{ ft.}$
 - $d = 21 \text{ ft.}, h = 30 \text{ ft.}$
 - $d = 24 \text{ ft.}, h = 40 \text{ ft.}$
- How many cubic feet of earth must be removed in digging a well 63 ft. deep and 3 ft. in diameter; how many cubic yards?
- If a cylindrical oil tank is 30 ft. high and 20 ft. in inside diameter, how many cubic feet does it hold?

4. A cylindrical drum of gasoline is 7 ft. high and 4 ft. in diameter. How long will the gasoline last if 2 cubic feet are used each day?

Capacities of Cylindrical Silos.



Twin Silos, 14 x 50 Feet.

When the inside of a silo has the shape of a cylinder, its volume can also be found by the formula: $V = \pi r^2 h$. Volume of a silo is usually measured in cubic feet.

Silage in a cylindrical silo weighs from 25 lb. to 45 lb. per cubic foot, according to the nature of the silage, the manner of packing and the depth of silage. A cubic foot of silage will weigh more in an average circular silo than in a trench silo, because of the greater depth in the former.

For a circular silo,

properly constructed and filled, the following averages are satisfactory:

1 cu. ft. of silage = 40 lb.

1 ton of silage = 50 cu. ft.

Problems in the Capacities of Cylindrical Silos

1. A circular silo is 21 ft. high and has an inside diameter of 10 ft. If the silo is full, find the weight of its contents in pounds.

2. A circular silo, 30 ft. high and 20 ft. in inside diameter,

is filled with silage. How long will the silage last, if 2400 lb. are used each day?

3. How many tons of silage can be stored in a silo that is 35 ft. deep and 18 ft. in inside diameter?

Suggestion: Divide the no. of cu. ft. by 50.

4. A farmer has a circular silo, 40 ft. high and 20 ft. in inside diameter, that he fills with silage. If he uses 2 tons of silage each day, how many whole number of days will the silage last?

5. A silo is 25 ft. high and 14 ft. in inside diameter. The silage crop on the farm averages 11 tons of silage to the acre. How many acres of the silage crop are needed to fill the silo?

Liquid Measure.

I. The standard gallon occupies 231 cubic inches. Dividing 1728 (the number of cubic inches in 1 cubic foot) by 231, the quotient is almost exactly 7.48. For ordinary practical computations, we may say that 1 cubic foot holds 7.5 (or $7\frac{1}{2}$) gallons.

II. One barrel equals 31.5 (or $31\frac{1}{2}$) gallons. Dividing 7.48 by 31.5, the quotient is approximately .24, and for practical purpose, we may say that 1 cubic foot contains .24 gallons.

RULE 21. To find the liquid capacity of tanks, etc.:

(a) The no. of gallons = no. of cu. in. $\div$ 231;

(b) The no. of gallons = no. of cu. ft. $\times$ 7.5;

(c) The no. of barrels = no. of gal. $\div$ $31\frac{1}{2}$;

(d) The no. of barrels = no. of cu. ft. $\times$.24.

6. How many gallons of water can be stored in a circular cistern, 7 ft. deep and 6 ft. in inside diameter?

7. How many gallons of water are in a circular tank, 10 ft. in inside diameter, if the water is 8 ft. deep?

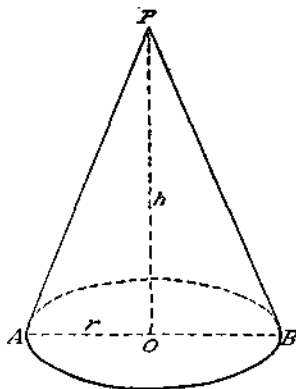
8. A water pump delivers 400 gallons of water in 1 hour. Express in barrels per hour.

9. A cylindrical water tank is 14 ft. in inside diameter and 30 ft. deep. How many barrels of water can it hold?

Finding the Volume of a Cone.*

If grain or sand is poured from a small opening upon a flat surface, a pile is formed having approximately the shape of a cone. The roofs of many silos are built in a conical shape.

The **base** of a circular cone is a circle. The solid tapers from the base to a point, called the **vertex**. Straight lines drawn from any point in the circumference of the base to the vertex lie in the surface of the cone. The **height** of the cone is the perpendicular distance from the vertex to the base. In the right circular cone shown above, line OP is the **altitude**.



The volume of a cone equals $\frac{1}{3}$ of the product of the area of its base by its height. Below is the formula.

$$V = \frac{1}{3} \pi r^2 h \quad \text{or} \quad V = \frac{\pi r^2 h}{3}$$

You can test this formula by a simple experiment. Use a small tin can or other cylinder constructed out of cardboard. Construct a cone having the same base and height as the cylinder. Fill the cone with sand, sawdust, or other handy material, and carefully pour the contents into the cylinder. Fill the cone again and pour into the cylinder. How many times the volume of the cone is the cylinder?

The volume of a pyramid also equals $\frac{1}{3}$ of the product of the area of its base by its height. The trylon of the World's Fair of 1939 is an illustration of a pyramid.

1. How many cubic feet of sand are there in a conical-shaped pile, 10 feet high and 14 feet across its base?
2. Find the number of bushels in a conical-shaped pile of rye; the diameter is 12 ft., and the height is 7 ft.
3. How many bushels of wheat are there in a conical-shaped pile, if $d = 10$ ft. and $h = 10$ ft.?

* The remainder of this chapter is optional.

MEASURING THE AMOUNT OF HAY IN STACKS *

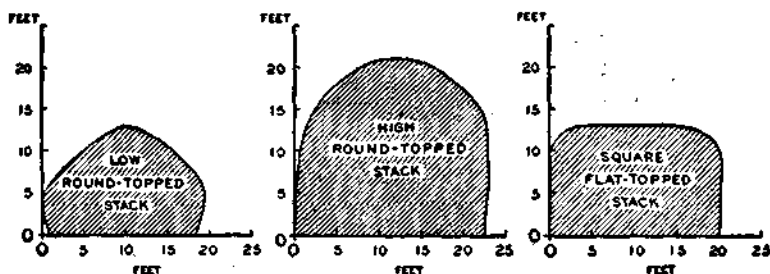
Large quantities of hay are frequently bought and sold in stacks. Direct calculation of the amount of hay in the stack avoids the time and labor required to load and haul the hay to scales. In fact, scales are often not available.

How can you determine the volume of hay stacks, and then the weight of the hay, without the use of scales? You can realize that stacks are not often regular in shape. They are not exact rectangular solids, prisms or cylinders that can be solved by the usual formulas. As the result of scientific investigations in State agricultural experiment stations, rules have been developed for the measurement of hay in stacks, giving very accurate results.

Oblong or Rectangular Stacks.

The volume of a stack of this shape equals the length multiplied by the area of the cross-section (same rule as volume of a prism). The average length is determined easily by measurement, but finding the area of the cross-section is more difficult, because of the variety of shapes of stacks.

An oblong hay stack is usually one of three types: a low, round-topped stack; a high, round-topped stack; or a square, flat-topped stack. Rules have been formulated for the volume of each type of stack. Only three measurements are necessary for the use of these rules, namely, length, width and over, all



Cross-Sections of Typical Oblong Stacks.

* U. S. Dept. of Agr. Leaflet No. 72.

easily made. Length is the average length of the stack. The cross-section is calculated from the width, which is the width of the stack at the ground, and the over, which is the distance from the ground on one side of the stack over the stack to the ground on the other side.

The rules for finding the volumes of each type of stack are as follows:

For low, round-topped stacks,

$$(.52 \times O - .44 \times W) \times W \times L.$$

For high, round-topped stacks,

$$(.52 \times O - .46 \times W) \times W \times L.$$

For square, flat-topped stacks,

$$(.56 \times O - .55 \times W) \times W \times L.$$

In these rules, O represents the over, W represents the width, and L represents the length.

The Number of Cubic Feet of Hay Per Ton.

The weight of one cubic foot of hay in a stack is not necessarily always the same for a certain kind of hay. The amount of moisture is probably the main factor in causing variations in the weight of hay in the stack. The following averages have been obtained from the studies at the experiment stations, and can be used with fairly good results:

Kind of hay	Length of time in stack	
	30 to 90 days	Over 90 days
Alfalfa	485 cu. ft. per ton	470 cu. ft. per ton
Timothy and timothy mixed..	640 cu. ft. per ton	625 cu. ft. per ton
Wild	600 cu. ft. per ton	450 cu. ft. per ton

Example. An oblong stack, of the low, round-topped type, containing alfalfa hay, is 20 feet wide, 42 feet over, and 40 feet long. How many tons of hay are there, if the stack has been standing for over 4 months?

$$\begin{array}{ll} O = 42 \text{ ft.} & V = (.52 \times O - .44 \times W) \times W \times L \\ W = 20 \text{ ft.} & V = (.52 \times 42 - .44 \times 20) \times 20 \times 40 \\ L = 40 \text{ ft.} & \end{array}$$

Subtract:	$W \times L$	Multiply:
$.52 \times 42 = 21.84$	20	(1) 13.04
$.44 \times 20 = 8.80$	40	(2) 800
(1) 13.04	(2) 800	10,432 cu. ft.

Divide 10,432 by 470 (table above); 22.2 tons, *answer*.

Problems in the Amounts of Hay in Oblong Stacks.

1. A high, round-topped, stack of wild hay, which has been standing for about 2 months, measures 20 feet wide, 48 feet over, and 50 feet long. How many tons of hay are there in the stack?

2. Find the number of tons of timothy hay in an oblong stack, of the square, flat-topped type. The stack measures 25 feet wide, 70 feet over, and 40 feet long, and has been standing for one month.

3. A low, round-topped stack of mixed timothy hay, is 30 feet wide, 65 feet over, and 40 feet long. If the stack has been standing for 1 month, what is the value of the hay at \$6.70 per ton?

4. How much should be paid for an oblong stack, of the square, flat-topped type, containing alfalfa hay, when the price is \$8.80 per ton? The stack is 20 feet wide, 55 feet over, and 50 feet long, and has been standing for about four months.

Round Stacks.

The formula that was developed for finding the volume of a round stack is as follows:

$$V = (.04 \times O - .012 \times C) \times C^2$$

In this formula, C represents the circumference or distance around the stack at the ground, and O represents the over or distance from the ground on one side over the peak to the ground on the other side. It is advisable to take an average of two over measurements at right angles to each other for a more accurate result.

A table at page 285 of the appendix gives the volumes of

round stacks when the circumference is between 45 and 98 ft. and the over is between 25 and 50 ft. The formula need be used only for stacks having circumferences and overs greater or less than those given in the table. For the number of tons of hay in round stacks, use the table of number of cubic feet per ton, on page 77.

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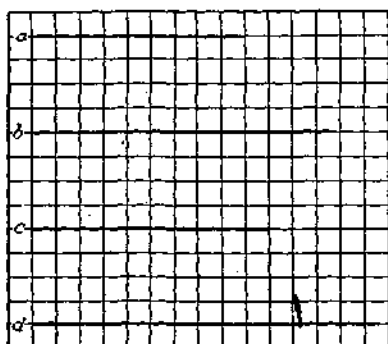
Chapter VIII

THE DRAWING OF FARM PLANS

Wise planning of the farmstead will repay the farmer in many respects. You can economize in travelling time to and from the fields, and in the costs of fencing, drainage, water supply and irrigation. On an established farm, many improvements could probably be made in the arrangement of buildings, fields and working facilities. The farmer has an extensive opportunity for such planning when he procures unimproved land for development. These plans should be worked out on paper.

To draw such plans, you must reduce the size of all dimensions so that they will fit on the paper used. This is called **drawing to scale**. Geographical maps, surveyors' maps, architects' plans, building plans and blueprints, are also drawn to scale. You will find a knowledge of scale drawings of further help in reading of plans for various farm structures. Scale drawings are useful in planning the placement of crops, and in the arrangement of crop rotations.

Reducing Lengths to Scale.



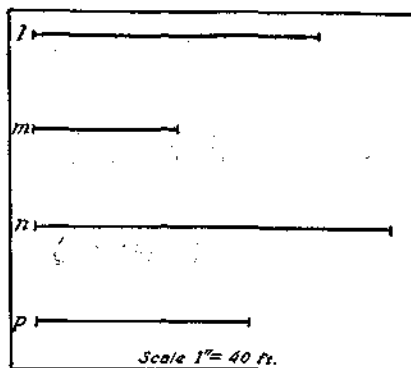
I. Squared paper can be used conveniently for drawings of rectangular figures. A scale may be indicated on the drawing by a statement such as 1 space = 20 feet, which means that 1 space on the drawing represents 20 feet of actual length.

At the left, the scale is 1 space = 10 feet. Line a is 9 spaces on the drawing, and thus 9×10 , or 90 feet in actual length. Line b = $12\frac{1}{2} \times 10$, or 125 feet long. What are the actual lengths of c and d?

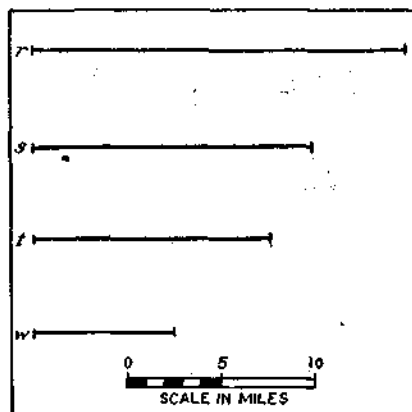
To reduce an actual length to scale length: Divide the actual length by the value of the scale unit. Thus, if a distance of 164 ft. is to be drawn to a scale of 1 space = 8 feet, make its drawing length $164 \div 8$, or $20\frac{1}{2}$ spaces.

II. When unruled paper is used, the scale might be: 1 inch = 30 feet; 1 inch = 5 rods; $\frac{1}{4}$ inch = 5 feet; $\frac{1}{8}$ inch = 2 feet; and others.

The scale at the right is: 1 inch = 40 feet (same as $\frac{1}{4}$ inch = 10 ft., etc.). Line 1 is $1\frac{1}{2}$ in. on the drawing. Therefore its actual length is $1\frac{1}{2} \times 40$, or 60 ft. As line m is $\frac{3}{4}$ in. on the drawing, it is $\frac{3}{4} \times 40$, or 30 ft. in actual length. What are the real lengths of lines n and p?



In calculating scale lengths with scales such as $\frac{1}{8}$ in. = 5 ft., convert to the unit scale first, namely, 1 in. = 40 ft. Then the scale length for 315 ft. is $7\frac{7}{8}$ in., etc.



III. The **graphic scale** is the type indicated on a drawing by a line marked with subdivisions, similar to a ruler. The markings are not necessarily $\frac{1}{8}$ ths, $\frac{1}{4}$ ths, etc., but may be tenths of an inch, units in the metric system, or any equal subdivisions.

If the subdivisions on a graphic scale are not the same as the fractions on your ruler, use a strip of

paper. Mark the length of the line on the edge of the paper, and match its length with the scale. Find r , s , t , w , in this way.

PRACTICE IN CONVERTING AND READING LENGTHS TO SCALE

1. If a scale 1 space = 4 feet is used, what are the scale lengths of the following actual lengths:

- (a) 28 ft. (c) 10 ft. (e) 15 ft. (g) $12\frac{1}{2}$ ft.
 (b) 24 ft. (d) 18 ft. (f) 31 ft. (h) $9\frac{1}{2}$ ft. ?

2. Using a scale 1 inch = 20 feet, find the scale lengths of the following actual lengths:

- (a) 80 ft. (c) 50 ft. (e) 25 ft. (g) 15 ft.
 (b) 40 ft. (d) 70 ft. (f) 65 ft. (h) 85 ft.

3. Find the scale lengths for the following actual lengths if the scale is $\frac{1}{4}$ inch = 10 feet: (Suggestion: This scale is equivalent to 1 inch = 40 feet).

- (a) 400 ft. (c) 180 ft. (e) 205 ft. (g) 154 ft.
 (b) 240 ft. (d) 300 ft. (f) 345 ft. (h) 318 ft.

Note: For lengths such as in (g) and (h), it is not possible to reduce to an exact fraction of an inch corresponding to a subdivision on an ordinary ruler. In such cases, you should estimate to the smallest division on the ruler (usually sixteenths).

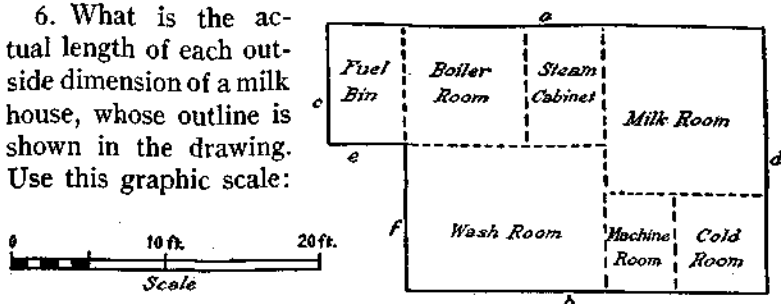
4. The scale used on a plan of a barn for the breeding herd is 1 inch = 20 feet. Find the actual lengths of the dimensions that have the following lengths on the drawing:

- (a) $5\frac{1}{2}$ in. (c) $\frac{1}{2}$ in. (e) 3.1 in. (g) 0.3 in.
 (b) $\frac{1}{4}$ in. (d) $\frac{3}{8}$ in. (f) 1.4 in. (h) 1.7 in.

5. In a plan of a shed-roof laying house for poultry, the scale used is 1 in. = 10 feet. If the following are lengths on the drawing, what are the actual lengths they represent?

- (a) 4 in. (c) $\frac{1}{4}$ in. (e) $10\frac{1}{8}$ in. (g) 1.9 in.
 (b) 5 in. (d) $\frac{3}{4}$ in. (f) $\frac{5}{8}$ in. (h) 1.6 in.

6. What is the actual length of each outside dimension of a milk house, whose outline is shown in the drawing. Use this graphic scale:



How to Make a Scale Drawing.

In making a scale drawing of a field of rectangular or other shape, (1), reduce each dimension by the same scale; and (2), use the same angles in the drawing as in the actual figure. The actual figure and the drawn figure will then have the same shape, and are said to be **similar polygons**. Mathematical figures are similar when their respective sides have the same ratio, and their respective angles are equal. A camera automatically reduces size, while it maintains the original shape of the object photographed.

To determine the scale: Divide the actual length of the line by the available space on the paper. As an example, to find a scale for a 225-foot length to be drawn in a 6-inch space, divide 225 by 6. Round off the quotient to a *larger* number, and you have the convenient scale: 1 inch = 40 feet.

In choosing a scale for a figure, you must be sure that this same scale is suitable for all the dimensions.

Example 1. Draw to scale a rectangular farm 385 rods long and 165 rods wide.

Suppose the available space is 11 in. x 7 in., after making allowances for the margin.

(1) $385 \div 11$, rounded off, permits the scale $1'' = 40$ rd.

(2) Using the same scale, $7 \times 40 = 280$ rods, which is ample space for the width of 165 rods.

Example 2. Draw to scale a rectangular farm 230 rods long and 210 rods wide.

Suppose the space on the paper is 12 in. x 7 in., after allowing for the margin.

- (1) Round off the quotient of $230 \div 12$. The scale may be $1'' = 20$ rd.
- (2) Using the same scale, $7 \times 20 = 140$ rd., insufficient for the width of 210 rd. This scale cannot be used.
- (3) Divide 210 by 7. $1'' = 30$ rd. is a proper scale for a ruler in tenths. Otherwise, use $1'' = 32$ rd.

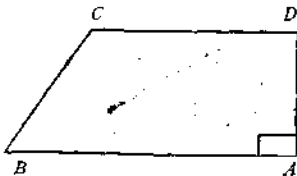
Drawing instruments. Perpendicular and parallel lines can be made easily and accurately on drawings by use of the T-square, shown on page 14, and the draftsmen's triangles.

MAKING SCALE DRAWINGS.

Quadrilaterals.

1. Draw a diagram of a rectangular field $250' \times 175'$. Use the scale $\frac{1}{4}'' = 10'$ (equivalent to $1'' = ?$).

2. A field having the shape of a trapezoid, of the type shown at the right, has an altitude of 25 rd., and upper and lower bases of 46 and 58 rd., respectively.

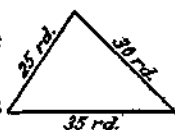


- (a) Draw its diagram, using the scale $\frac{1}{2}'' = 8$ rd.
 - (b) Find the actual length of side BC by measuring its scale length and then converting with the scale.
3. A field has the shape of a parallelogram. The longer side is 70 yd., the shorter side is 40 yd., and the angle between them is 30° .
- (a) Draw the diagram using the scale $1'' = 20'$.
 - (b) On the drawing, construct an altitude (perpendicular) between the bases. Use the scale length to find the actual length of the altitude.
 - (c) Calculate the area of the field.
4. Draw a diagram of a rectangular field $205' \times 115'$, in a space $6'' \times 4''$. Determine your own scale.
5. Draw a diagram of a square field 35 rd. on a side, in a space $4'' \times 3''$. Find your own scale.

Note: Using scale drawings. You can see from example 2b that a scale drawing can be used for the purpose of finding a distance that may be inaccessible because of swamp, heavy underbush, and other inconveniences. The actual length is determined from the finished drawing. Examples 3b and 3c show how area can be found from a completed scale drawing. You can avoid the necessity of actual measurement of the altitude of a figure by measuring it on the drawing. However, a careful diagram is essential for good results.

Triangles.

A scale drawing of a triangle can be made when only the length of each side is known; angles are not needed. At the right, compasses were used with scale lengths of $\frac{5}{8}$ ", $\frac{3}{4}$ " and $\frac{7}{8}$ ".



6. Make scale drawings of these triangular fields, draw the altitude of each, and find the area; scale $1'' = 16$ rd.: (a) Sides are 45, 39, 42 rd. (b) Sides are 52, 50, 34 rd.

FARM PLANNING.

1. A farmer is laying out a triangular field for tractor plowing. The lengths of its sides are 80 rd., 70 rd., 70 rd.

(a) Draw a diagram of the field in a square space, $4'' \times 4''$. Determine your own scale.

(b) Construct an altitude of the triangle on the drawing. Measure its scale length, and find its actual length by scale.

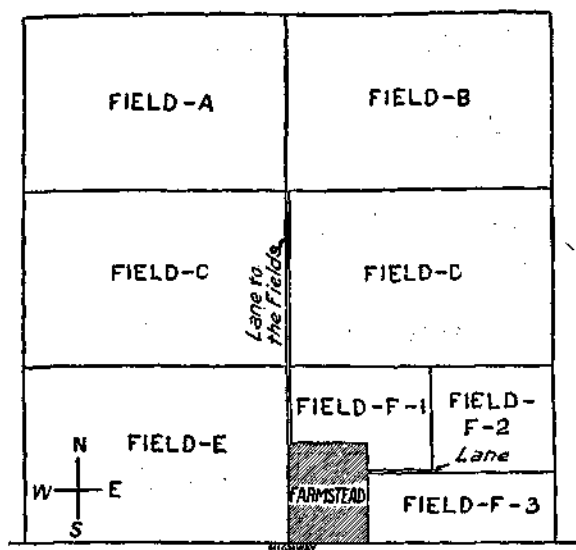
(c) How many acres does the field contain?

2. A farmer is planning the irrigation of his farm by the border method. The farm has the shape of a parallelogram; its sides are 800 ft. and 1525 ft., and the angle between them is 80° . Choosing your own scale and space, draw the diagram.

3. Below is a sketch of an arrangement of farm space having the advantages of direct access to all fields from the farmstead, savings in fencing and in piping, and in situation of the farmstead at the highway. This layout, suggested in a bulle-*

* U. S. Farmers' Bull. No. 1132.

tin of the United States Department of Agriculture, also provides for a three field hog pasture rotation.



Arrangement for a Three Field Hog Pasture Rotation.

The dimensions of the farmstead and fields are as follows:

Fields A, B, C, D, E:—each 120×80 rd.

Field F 1:— 60×45 rd., less piece for farmstead, which is 30×10 rd.

Field F 2:— 60×45 rd.

Field F 3:— 90×35 rd.

Farmstead:— 30×45 rd.

(a) Draw this plan, using the scale $1'' = 80$ rd.

Sketch in the lanes.

(b) Find the acreage of each field, and the farmstead.

Projects in Scale Drawing.

I. Draw diagrams to scale of fields having the following shapes, and calculate their areas from the drawings:

1. Rectangle.
2. Triangle.
3. Parallelogram.
4. Trapezoid.

II. Make a scale drawing of an irregular shaped field having straight line boundaries. Compute its area by subdividing the drawing into figures of standard shapes.

III. Draw to scale a diagram of an irregular shaped field having one or more curved line boundaries. Compute its area by using "average" straight lines on the drawing.

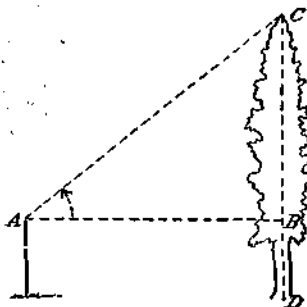
IV. Draw to scale your school grounds, including the buildings, yards and walks.

V. Draw a diagram to scale of your farm, showing the location of the fields and farmstead, all roads, lanes, drains and fences, and all buildings, in block form.

VI. Make a scale drawing of the farmstead, including in detail all buildings, trees, shrubbery, walks, lanes, etc., and all accessories, such as scales, watering troughs, pens, feeding places, etc.

VII. Find the height of a tree by using a scale drawing, as follows:

- (a) Measure a suitable base line horizontally from the foot of the tree, as 50 ft., 75 ft., or 100 ft. (Line AB).
- (b) Measure the angle of elevation to the top of the tree at point A, with any available instrument (BAC).
- (c) Measure the correction for the height of the instrument (length BD).
- (d) Draw a diagram to scale on squared paper of triangle ABC, using the length AB, the angle BAC, and the right angle ABC.
- (e) Measure the scale length of CB and compute its actual length from the scale.
- (f) The height of the tree equals $CB + BD$.





VIII. Find an inaccessible distance AC by using a scale drawing on squared paper. Measure line AB, and angles A and B.

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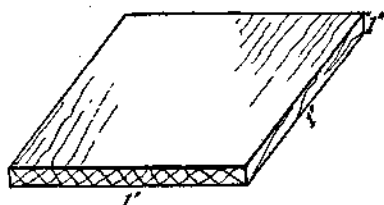
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Chapter IX

MEASUREMENT OF LUMBER AND TIMBER

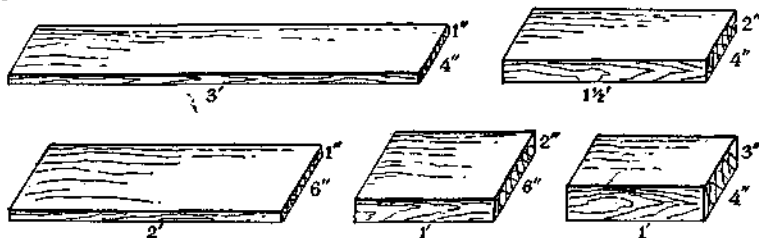
THE unit of lumber measure is 1 board foot (bd. ft.), also called 1 foot, board measure (1 ft., B.M.). A board one foot long, one foot wide, and one inch thick, is one board foot.

If 1 cubic foot of lumber were cut into boards each 1 inch thick, and 1 foot square, theoretically this should produce 12 board feet, in inch boards.



The volume of a board foot is 144 cubic inches ($12'' \times 12'' \times 1''$). In actual practice, the board foot might contain slightly less volume, because the thickness of the board may be less than 1 inch. Nevertheless, the charge is based upon the full inch. The manufacturer is thus able to compensate for losses caused by the width of the saw kerf (the amount of wood taken out by the saw in passing through), and in planing and finishing boards.

Board-foot measure is applied to lumber of all sizes. Lumber more or less than 1 foot wide, and more than 1 inch thick, is measured in board feet. Explain why each of the following pieces is exactly 1 board foot:



Number of Board Feet in Pieces of Lumber.

Lumber is usually sawed at the mills an even number of feet in length; mostly 10', 12', 14', and 16' long. The widths are whole number of inches, customarily an even number. Thicknesses are also measured in whole number of inches, although a 2" thickness may prove to be $1\frac{7}{8}$ " on close measurement, as has been explained.

If a board has a cross-section measuring 12" x 1", and is 10' long, it contains 10 board feet, each 1' long, 12" wide, and 1" thick. How many board feet are there in boards that have the cross-section 12" x 1", and are 12', 14', and 16' long, respectively? Length is one of the factors in determining the number of board feet in a piece of lumber.

A board that has a surface measuring 1' x 1' and a 2" thickness, contains 2 bd. ft. What is the number of board feet in pieces of plank, 1' x 1' in surface, and 2", 3", and 4" thick, respectively? Another factor in determining the number of board feet in a piece of lumber is the number of inches in its thickness.

In considering width in relation to the number of board feet, you must observe that a standard board foot has a width of 1 foot, whereas the usual measurement of width of lumber is in inches. A board 1' long, 1" thick, and 6" wide, is only $\frac{1}{2}$ board foot, because its width is $\frac{6}{12}$, or $\frac{1}{2}$ of the width of the standard board foot. Thus, a plank 12' long, 4" wide, and 2" thick, contains $12 \times \frac{4}{12} \times 2$, or 8 board feet. Multiplying $12 \times 4 \times 2$, and dividing the result by 12, gives the same result (this work can be simplified by cancellation).

To find the number of board feet in any regular piece of sawed lumber, use the following rule:

RULE 22. The number of board feet equals the length in feet times the width in inches times the thickness in inches, divided by 12. Use cancellation.

$$\text{FORMULA:} \quad \text{Bd. Ft.} = \frac{l \ w \ t}{12}$$

l = length in ft.; w = width in in.; t = thickness in in.

Example. Find the number of board feet in 6 pieces (pcs.) of 2" x 4" x 10', hemlock.

Formula: For 6 pcs.:

$$\text{Bd. Ft.} = \frac{l \times w \times t}{12} \quad \text{Bd. Ft.} = \frac{6 \times 2 \times 4 \times 10}{12} = 40 \text{ bd. ft.}$$

Note: In practice, the dimensions of lumber are usually given as above, without specifying the length, width and height. However, the formula can be used without distinguishing the dimensions, provided two of the dimensions are in inches (assumed to be width and thickness), and one dimension is in feet (assumed to be the length).

Find the number of board feet in the following lumber:

- | | |
|---------------------------|----------------------------|
| 1. 22 pcs. 1" x 12" x 14' | 11. 4 pcs. 2" x 6" x 12' |
| 2. 11 pcs. 1" x 10" x 18' | 12. 12 pcs. 2" x 4" x 10' |
| 3. 15 pcs. 1" x 5" x 12' | 13. 8 pcs. 3" x 4" x 14' |
| 4. 24 pcs. 1" x 7" x 14' | 14. 9 pcs. 2" x 4" x 18' |
| 5. 17 pcs. 4" x 6" x 10' | 15. 5 pcs. 2" x 12" x 16' |
| 6. 18 pcs. 2" x 2" x 14' | 16. 7 pcs. 2" x 8" x 12' |
| 7. 14 pcs. 1" x 5" x 18' | 17. 20 pcs. 2" x 4" x 18' |
| 8. 18 pcs. 1" x 10" x 14' | 18. 6 pcs. 2" x 4" x 14' |
| 9. 9 pcs. 4" x 6" x 14' | 19. 14 pcs. 2" x 10" x 12' |
| 10. 6 pcs. 2" x 2" x 16' | 20. 3 pcs. 3" x 4" x 16' |

Cost of Lumber.

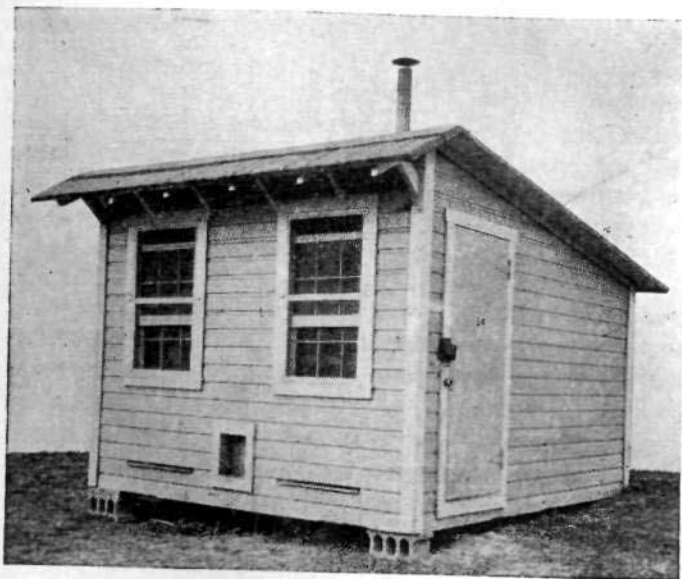
Most lumber is sold by the thousand board feet, M feet, B.M. The lumberyard may quote you a price of \$38 per M for cypress, or \$34 per M for white pine, and prices for other lumber per thousand. You calculate the number of board feet by Rule 22, then divide by 1000 to change to M board feet, and multiply by the price per M. A shorthand method of dividing by 1000 is to move the decimal point 3 places to the left.*

* 21. Work out Special Drill number 12, on page 275, in division by multiples of 10.

RULE 23. To change board feet to thousand board feet, move the decimal point in the number of board feet 3 places to the left.

Example. What is the cost of 28 rafters, each 2" x 6" x 16' at \$29.54 per M.

- (1) Bd. Ft: 28 pcs. $2'' \times 6'' \times 16' = 448$ bd. ft.
- (2) 448 bd. ft. = .448 M bd. ft.
- (3) Multiply: $\$29.54 \times .448 = \13.23392
- (4) As the answer must be in dollars and cents, there should be only 2 decimal places. Use only the third place in rounding off. \$13.233 becomes \$13.23.



A Colony Brooder House
 Courtesy of H. C. Kandel.

Find the cost of the following lumber:

1. 300 pcs. 1" x 10" x 18' at \$25.30 per M.
2. 180 pcs. 2" x 4" x 10' at \$24.60 per M.
3. 120 pcs. 1" x 5" x 14' at \$39.50 per M.

4. 150 pcs. 2" x 6" x 16' at \$31.40 per M.
5. 250 pcs. 4" x 6" x 12' at \$28.20 per M.
6. 360 pcs. 3" x 4" x 14' at \$27.41 per M.
7. 170 pcs. 2" x 8" x 18' at \$32.18 per M.
8. 280 pcs. 1" x 7" x 12' at \$42.58 per M.
9. 140 pcs. 1" x 12" x 16' at \$26.43 per M.
10. 290 pcs. 2" x 4" x 10' at \$25.84 per M.

11. A colony brooder house is 10 x 14 feet, and will accommodate from 300 to 400 chicks. The lumber estimate for the structure is as follows:*

<i>Lumber</i>	<i>Size</i>	<i>Pieces</i>	<i>Length</i>	<i>Board Measure</i>
Framing:	Inches	Number	Feet	Feet
Runners	4 x 6	2	16	
Joists and braces	2 x 6	11	10	
Studs	2 x 4	1	12	
Studs and horizontals	2 x 4	7	14	
Studs	2 x 4	2	16	
Rafters	2 x 4	6	16	
Studs, braces and horizontals..	2 x 4	7	10	
Roof plates	2 x 4	3	10	
Sheathing for roof and fascia ...	1 x 6	..	440	
Tongue-and-groove flooring and siding	1 x 4	..	1725	
Total	..	..	..	

In addition, you will need sash, frames, prepared roofing, poultry wire, hinges, nails, paint, etc.

(a) Copy the above lumber bill. Calculate and fill in the number of board feet for each item.

(b) Find the total number of board feet.

(c) Find the total cost of the lumber at \$32 per M.

12. A farmer received the following bill for lumber, which is a part of the lumber and other materials that he used in the

* U. S. Farmers' Bull. No. 1554.

construction of a simple milk house. Find each amount and the total due the lumberyard:

422 ft. of 2" x 4", hemlock, at \$27.50 per M.

364 ft. of 1" x 6", hemlock, at \$28.75 per M.

30 ft. of 1" x 14", yellow pine, at \$27.80 per M.

TIMBER

A great deal of timber is sold by the piece. Each piece of timber must meet certain requirements as to size and quality. The price per piece varies according to these details. The following are a few illustrations:

Poles. Poles must be 7 inches in diameter at the top. They may be any specified length, although usually multiples of 5 feet, as 35 ft., 40 ft., or 45 ft. Prices range from about \$4 each for 25-foot poles to \$15 or more for 50-foot poles.

Posts. Posts are usually 7 feet long, and of a specified diameter at the small end. Prices may vary from 10 cents to 50 cents each, depending on the kind of wood, the quality, the diameter, and whether they are round or split.

Ties. Railroad ties of standard-gauge are either 8, 8½, or 9 feet in length, and narrow-gauge ties run from 5 to 7 feet in length. Grade numbers specify the dimensions. For example, one grade requires a section 7" x 9", straight edge on all sides; another must have a section 6" x 6", straight edge on top and bottom only; and so on. Price variation depends upon the kind and quality of wood, and shipping facilities. There is also a price difference of about 10 to 15 cents between successive grades. The smallest size is about 15 cents per tie, and the largest grade sells for about \$1 each.

Some timber is sold by the **linear foot**, that is, the running foot. The price is so much per foot of length. This means that the value of the piece is determined by its length only, while the diameter or girth (circumference) is not considered. Pieces of small diameter are frequently sold in this way. Pilings, and sometimes bolts, are sold by the linear foot.

Timber is sold by the **cord** for firewood, pulp wood, cooper-

age, distillation, and other uses. One cord contains 128 cubic feet (see page 64), including the air space between the pieces. The actual wood in one cord is about 70% of this amount, or an average of 90 cubic feet per cord.

Measuring the Contents of Logs in Board Feet.

An important use of timber is for lumber production. The log is sold by the number of board feet of lumber that can be obtained from it. How can you determine this number in advance of the actual sawing of the log?

Tables, called log rules, log tables, or log scales, have been constructed, which estimate the contents in board feet of sound logs of different lengths and diameters. These estimates deduct the losses due to the curved surface of the log, and the width of the saw kerf. As there are different bases for these deductions, two rules may disagree in the number of board feet in a log having a certain length and diameter. In some states, and localities, the law or custom decrees that only a certain log rule shall be used. A table giving log volumes close to the actual amounts that can be sawed from a log is the **International rule**. See page 287.

Scaling. The process of measuring the number of board feet in a log is called scaling. The length of the log can be measured conveniently with a measuring stick 8 feet long. About 3 inches should be allowed for trimming of rough edges at the mill. The diameter measured is inside the bark at the top (small end) of the log. An average may be obtained by taking several measurements. Round off the diameter to the nearest inch; $15\frac{1}{8}$ becomes 15, $23\frac{3}{4}$ becomes 24, and for $18\frac{1}{2}$, use an amount in the table equally between 18 and 19 in. Read the number of board feet in the log from the log table used. Deductions should be made for defects in the log.

A **scale stick** is graduated in inches, and has printed on it the number of board feet for logs of different sizes in diameter and length. If much scaling has to be done, a scale stick should be used, as the contents in board feet can be read directly from the instrument.

Use the International rule (p. 287) to find the no. of bd. ft.:

	a	b	c	d	e	f	g	h	i	j
d (in.) =	15	5	31	28	10	25	13	$32\frac{1}{4}$	$37\frac{3}{4}$	$22\frac{1}{2}$
l (ft.) =	18	11	17	19	12	18	20	14	12	15



A black walnut log, 35 inches in top diameter by 12 feet in length, which brought \$135 per thousand feet, or \$95.85 for the log, at the railroad. (The original owner, a farmer, sold the whole tree, standing, for \$50; the buyer felled it, at a cost of \$15, and sold it there for \$138.26; it was resold without being moved for \$164.84, and later sold to a large sewing-machine factory).

Courtesy of the United States Department of Agriculture.

Estimating Standing Timber.

If the farmer sells standing timber, he should be able to estimate closely the number of thousand feet, board measure, that can be obtained from the woodlot. Even if he does not intend to sell directly from the tract, this information would be useful for cutting purposes.

Two methods of **timber-estimating**, called **timber-cruising**, are in use:

- (1) The tree-to-tree count, for small areas only;
- (2) The sampling method, in which a count is made for all the trees in a representative plot or strip, and this figure is used as the average for the entire timber land.

Method (1) is advisable for tracts up to 50 acres in area. In either plan, the timber-cruiser must be able to estimate the number of board feet of lumber in a standing tree.

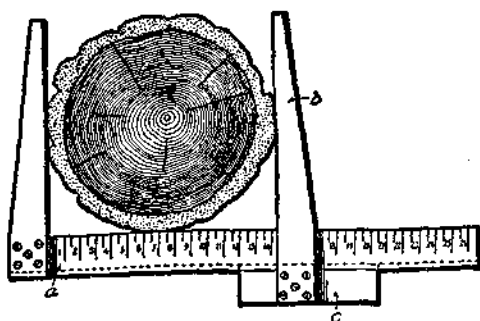
The Number of Board Feet in a Tree.

Tree measurement involves finding the diameter and height of the standing tree. The number of board feet of lumber that can be sawed from it is obtained from a **volume table**. A volume table gives the same information for a whole tree as a log rule gives for a log: namely, the average number of board feet contained in trees of given sizes.

There are volume tables for the different species of wood. Trees differ in shape, thickness of bark, and taper toward the top, and thus two trees having the same height and diameter may have different contents. Each table contains estimates based upon the averages of large numbers of felled trees. For satisfactory results, the tables should be used only for a large number of trees, or for trees of average form. General volume tables for hardwood, and for softwood trees, are set forth in the appendix at pages 288, and 289.

Standing timber is also estimated without volume tables. An estimate is made of the number of 16-foot logs in the height of the tree, making deductions for the stump and the unmerchantable part of the tree at the top. The diameter inside the bark, at the top of each log, is also estimated. This information is recorded on special tally sheets, and the contents of the logs are determined later from log tables.

Measuring diameter. The diameter of a tree is measured at breast-height, which is 4 feet 6 inches above the ground. This avoids the variability of stump heights. A number of instruments are available for the measurement of diameter: tree-scale sticks, cruising sticks, and tree calipers. Serviceable,



Tree Calipers

United States Department of Agriculture.

homemade calipers can easily be constructed. All these devices measure the diameter outside the bark, which is the measurement used in the volume tables. However, when working without volume tables, allowance must be made for

the thickness of the bark, as log tables are based upon inside diameter. This can be done by estimate, or with the aid of standard tables of bark thicknesses. For a set of such tables, see page 290, at the appendix.

Use the volume table on page 288, to find the number of board feet in the following hardwood trees:

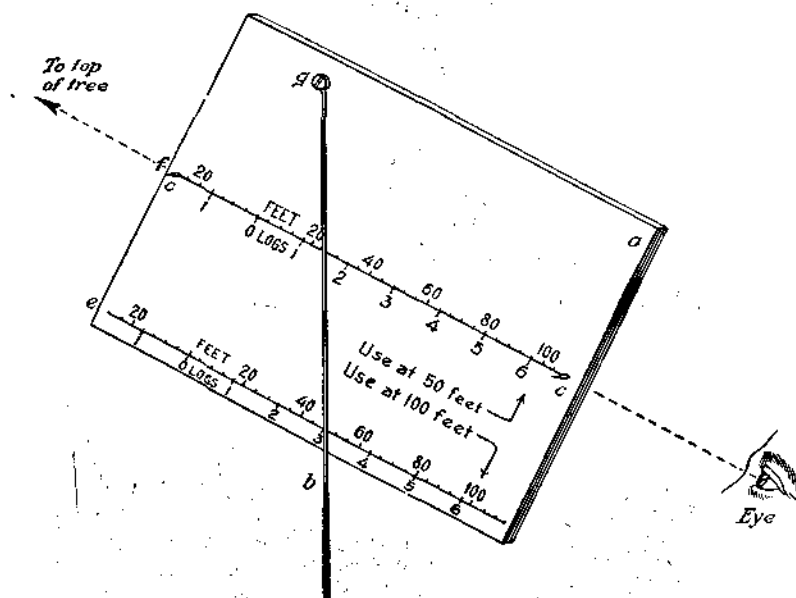
- | | |
|-------------------------|--------------------------|
| 1. Maple, 16" x 48'. | 6. Walnut, 40" x 56'. |
| 2. Hickory, 26" x 32'. | 7. Sycamore, 29" x 40'. |
| 3. Beech, 23" x 64'. | 8. Elm, 14" x 24'. |
| 4. Ash, 18" x 80'. | 9. Chestnut, 21" x 48'. |
| 5. Basswood, 11" x 16'. | 10. White oak 36" x 64'. |

Use the volume table on page 289, to find the number of board feet in the following softwood trees:

- | | |
|-----------------------------|-------------------------------|
| 11. White pine, 17" x 32'. | 16. Hemlock, 9" x 32'. |
| 12. Cypress, 19" x 48'. | 17. Red Spruce, 34" x 80'. |
| 13. Balsalm fir, 28" x 80'. | 18. Shortleaf pine, 9" x 40'. |
| 14. Spruce, 31" x 72'. | 19. Hemlock, 23" x 54'. |
| 15. Douglas fir, 34" x 80'. | 20. Red Spruce, 10" x 40'. |

Measuring height. The height of a tree is measured above the stump to the top of the merchantable part, and the length mentally divided into 16-foot logs and half-logs (8 feet), for use either with a volume table or a log rule. For example, a 72-foot log contains $4\frac{1}{2}$ logs of 16-foot length.

One instrument automatically uses the scale drawing method of page 87, for height of tree above and below eye level:



A Simple Homemade Instrument for Measuring the Heights of Trees.

United States Department of Agriculture.

- a— $\frac{1}{2}$ " board, 7" x 9".
 - b—10", heavy wire, loop end.
 - c—pointed brads as sights.
 - d—handle on back: 6" x 1" x $\frac{1}{2}$ ".
 - e—line $\frac{3}{8}$ " from lower edge, marked off to scale 1" = 1 log (16'), left and right from M, 2" from left edge.
 - f—line $\frac{3}{8}$ " from "e," marked to same scale, left and right from N, 2" from left edge of board.
 - g— $\frac{1}{2}$ " screw pivot for wire pendulum, $\frac{3}{8}$ " from "f."
- For greater detail, see U. S. Farmers' Bull. 1210, p. 33.

Heights of trees are measured by various hypsometers, cruising sticks, and shadow lengths. These devices are based upon

important and interesting mathematical principles, useful in many other ways besides measurement of the heights of trees. You will find them explained in the next chapter.

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Chapter X

RATIO AND PROPORTION

THE ratio of one quantity to another is the quotient of the first divided by the second. The unit of measure of both quantities must be the same, in order to make this comparison.

If one tree is 32 feet high and another is 24 feet, their ratio is: $\frac{32 \text{ feet}}{24 \text{ feet}} = \frac{4}{3}$. We say that the ratio of the heights of the two trees is 4 to 3, also written 4 : 3.

When mortar is made from 4 cubic feet of cement and 12 cubic feet of sand, the ratio of the materials is:

$\frac{4 \text{ cu. ft.}}{12 \text{ cu. ft.}} = \frac{1}{3}$, or 1 : 3, both reading 1 to 3.

If one piece of land yields an average crop of 30 bu. of corn per acre, and another, 15 bu. per acre, the ratio of these two yields is 30 bu. $\div$ 15 bu., or 2 to 1.

Find the ratio of each of the following sets of quantities, and write each ratio in two ways:

- | | |
|---------------------|-------------------------------|
| 1. 64 ft. to 16 ft. | 6. 2.7 cu. ft. to 8.1 cu. ft. |
| 2. 80 ft. to 56 ft. | 7. 18 bu. to 3 bu. |
| 3. 24 ft. to 72 ft. | 8. 15 acres to 6 acres. |
| 4. 10 ft. to 48 ft. | 9. 150 gal. to 80 gal. |
| 5. 4 in. to 3 ft. | 10. 700 lb. to 3 tons. |

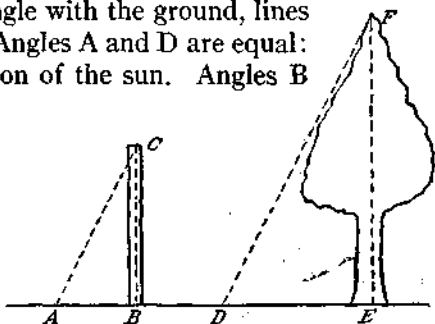
Proportion.

The lengths of the shadows of a pole and a tree are measured at a certain time of the day. The ratio of the lengths of these two shadows can then be expressed. For example, if the pole

has a shadow 2 feet long, and the tree's shadow is 12 feet, the ratio of the shadows is 1 to 6.

Suppose the height of the pole is measured, and is 10 feet long. Can you determine the height of the tree from these figures, without actual measurement of the height? What is the ratio of the length of the pole to the height of the tree?

Lines FD and CA are the directions of the rays of the sun. At any given time of the day, FD and CA have the same direction, and make the same angle with the ground, lines AB and DE respectively. Angles A and D are equal: each is the angle of elevation of the sun. Angles B and E are both right angles, and are equal to each other. We can now apply the following mathematical theorem, proved by more advanced mathematics: *If two angles of one triangle are equal respectively to two angles of another triangle, the two triangles are similar, that is, they have the same shape. Also, corresponding sides of similar triangles have the same ratio.* (See page 83).



Thus triangle ABC is similar to triangle DEF. The ratio of AB to DE is 2 ft. $\div$ 12 ft., or $\frac{1}{6}$. Therefore, the ratio of CB to FE must also be $\frac{1}{6}$. As CB is 10 feet, FE must be 60 feet, in order that the ratio be $\frac{1}{6}$. This is written:

$$\frac{2}{12} = \frac{10}{60}, \text{ or } 2 : 12 = 10 : 60, \text{ and is called a proportion.}$$

A proportion is a statement of the equality of two ratios.

From the illustration you can see that proportion can be used for the purpose of finding the height of a tree.

The proportion $\frac{2}{12} = \frac{10}{60}$ is read: "the ratio of 2 to 12 equals the ratio of 10 to 60". The first and last numbers of a proportion are called the *extremes* and the second and third numbers are called the *means*. The numbers 2 and 60 are extremes, and 12 and 10 are means.

Notice that $2 \times 60 = 120$, and 12×10 also equals 120. Try this with the proportion $\frac{3}{5} = \frac{9}{15}$, and $3 \times 15 = 5 \times 9$. In fact, this is an important working rule for any proportion:

The product of the means of a proportion equals the product of the extremes.

Some Algebra.

Problem: The shadows of a pole and a tree are 5 feet and 27 feet, respectively. If the pole is 13 feet long, what is the height of the tree?

(1) By similar triangles, the ratio of the two shadows equals the ratio of the two heights:—

$$\frac{5}{27} = \frac{13}{?}$$

If we represent the height of a tree by the letter "h" (or any other letter), this proportion becomes:—

$$\frac{5}{27} = \frac{13}{h}$$

(2) The product of the means equals the product of the extremes:—

$$5 \times h = 27 \times 13$$

This reduces to:—

$$5h = 351$$

(3) An expression such as $5h = 351$ is called an *equation*. The two sides of an equation are the terms to the left and to the right of the equal sign, in this case, "5h" and "351". The number 5 in front of the letter h is a *coefficient*.

We solve an equation by dividing both sides of the equation by the coefficient of the letter. Divide the two sides of this equation by 5:—

$$\frac{5h}{5} = \frac{351}{5}$$

(4) The quotients of the two divisions are:—

$$h = 70.2$$

(5) The height of the tree is approximately 70 feet.

The Shadow Method of Finding the Height of a Tree.

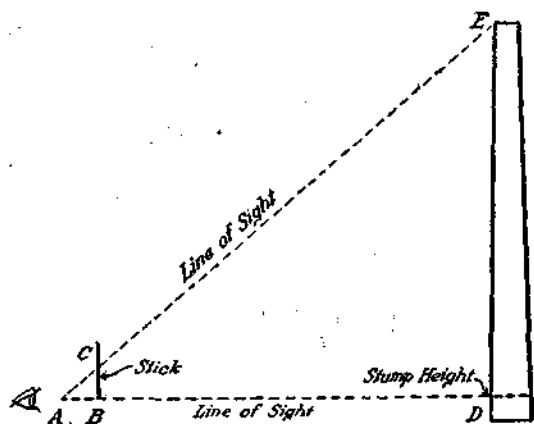
The actual arithmetic involved in the above problem consists of multiplying the length of the shadow of the tree by

height of the pole (27×13), and dividing the result by the length of the shadow of the pole (5). This is a rule for determining the height of a tree by comparison of its shadow with the length of the shadow of a pole of known length, set perpendicular to the ground.

Although this method of determining the heights of trees might be impracticable for an entire woodlot, it would be advisable to measure a number of heights in this way to train the person's judgment in estimating trees.

Measuring the Height of a Tree With a Cruising Stick.

The tree-scale or cruising stick is used to find heights of



trees in the following way. The stick is held at a specified distance from the eye, in a vertical position, while the observer is at a specified distance from the tree. A scale on an edge of the stick shows the height of the tree in 16-foot logs. The mathe-

mathematical basis for the graduations on the stick is the principle of two similar triangles.

Problem: To measure the height of a tree, a stick is held vertically, with its lower end in line with the foot of the tree. If the distance from the eye to the end of the stick is 2 feet, the distance from the observer to the tree is 59 feet (about the same as the distance from the eye to the foot of the tree), and the top of the tree is in line with the 1.6' mark on the stick, how high is the tree?

Solution: (1) Triangles ABC and ADE are similar.

(2) Therefore, we have $\frac{2}{59} = \frac{1.6}{h}$

(3) Solving this proportion,

$$\begin{aligned} \frac{2}{59} &= \frac{1.6}{h} \\ 2h &= 1.6 \times 59 \\ 2h &= 94.4 \\ \frac{2h}{2} &= \frac{94.4}{2} \\ h &= 47.2 \end{aligned}$$

(4) The tree is approximately 47 ft. in height.

Solve these proportions for the unknown letter:

1. $\frac{x}{4} = \frac{5}{2}$

6. $\frac{m}{9} = \frac{4}{11}$

11. $\frac{7}{30} = \frac{4.6}{r}$

2. $\frac{9}{d} = \frac{3}{8}$

7. $\frac{15}{35} = \frac{2}{p}$

12. $\frac{10}{b} = \frac{14}{5.7}$

3. $\frac{8}{12} = \frac{h}{3}$

8. $\frac{13}{12} = \frac{h}{9}$

13. $\frac{2h}{9} = \frac{21}{14}$

4. $\frac{9}{5} = \frac{72}{t}$

9. $\frac{x}{3.4} = \frac{20}{5}$

14. $\frac{5}{3n} = \frac{4}{30}$

5. $\frac{7}{y} = \frac{4}{5}$

10. $\frac{24}{7} = \frac{h}{2.5}$

15. $s : 12 = 5 : 6$

16. $9 : 2 = t : 18$

17. $5 : 7 = 3 : x$

18. $6 : h = 7 : 4$

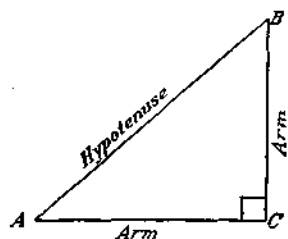
Direct and Indirect Measurement.

When we are able to apply the measuring instrument to a distance, and read the length directly from the instrument, we are using **direct measurement**. Is this always possible, or practical? What can be done to measure the width of a river, the distance across a lake or the height of a tall tree? How has man measured the distances to stars, the sun and the moon? These are problems of **indirect measurement**. Finding the heights of trees by the shadow method, with a tree-

scale stick, or by a scale drawing, are examples of indirect measurement.

The Right Triangle.

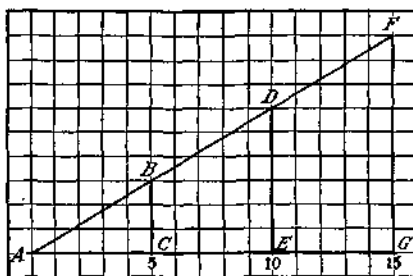
A basic figure in indirect measurement is the right triangle. A study of the parts of a right triangle will be helpful in this work.



Any triangle has six parts: three angles and three sides. In the right triangle, there are two acute angles and one right angle. The two sides which form the right angle are called **arms** (or legs), and the **hypotenuse** is the side opposite the right angle. In relation to each acute angle, there is an **opposite arm** and an **adjacent arm**. Side BC is the arm opposite acute angle A in triangle ABC, and side AC is the adjacent arm. The arm opposite acute angle B is side AC, and the adjacent arm is side BC.

A Start in Trigonometry.

Draw an angle of 31° with a protractor on squared paper. It is possible to draw any number of right triangles containing this angle. Complete one triangle by a perpendicular 5 units from the vertex A of the angle,



another at 10 units from A, and a third at 15 units from A. The three right triangles formed are ABC, ADE and AFG.

Observe the ratio of the arm opposite angle A to the arm adjacent to angle A in each triangle, by counting the number of units in each length, in the previous diagram:

$$\text{In triangle ABC, } \frac{BC}{AC} = \frac{3}{5} = .6.$$

$$\text{In triangle ADE, } \frac{DE}{AE} = \frac{6}{10} = .6.$$

In triangle AFG, $\frac{FG}{AG} = \frac{9}{15} = .6$.

In fact, for any right triangle containing the angle 31° , the ratio of the arm opposite this angle to the arm adjacent to this angle is always .6, to the nearest tenth.

Tangent of an Angle.

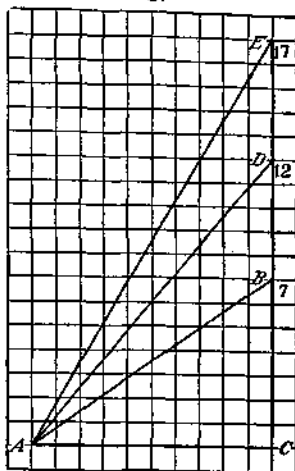
Draw another right triangle on squared paper, with an acute angle of 35° . Make the adjacent arm 10 units long, and count the number of units in the opposite arm. On the same figure, draw a right triangle having acute angle CAD equal to 50° , and a third right triangle with angle CAE equal to 60° .

Then you should find the following values for the ratio of the opposite arm to the adjacent arm:

$$\text{For angle CAB} = 35^\circ, \frac{BC}{AC} = \frac{7}{10} = .7$$

$$\text{For angle CAD} = 50^\circ, \frac{DC}{AC} = \frac{12}{10} = 1.2$$

$$\text{For angle CAE} = 60^\circ, \frac{EC}{AC} = \frac{17}{10} = 1.7$$



As Angle Increases, Tangent Increases.

These experiments have shown you that the ratio of the arm opposite an acute angle in a right triangle to the arm adjacent to this angle has a fixed value for an angle of a certain number of degrees. This ratio is called the **tangent of an angle**. For each number of degrees, the tangent of an angle has a different value.

RULE 24. For an acute angle A in a right triangle, $\text{tangent of angle A} = \frac{\text{the arm opposite angle A}}{\text{the arm adjacent to angle A}}$

$$\text{FORMULA:} \quad \tan A = \frac{\text{opp. arm}}{\text{adj. arm}}$$

Tangent of angle A is usually written in the abbreviated form "tan A." Mathematicians have computed to a number of decimal places these fixed ratios for angles of different number of degrees. The table on the next page contains the tangents of angles from 1° to 89° , correct to four decimal places. The information in this table is very useful in indirect measurement.

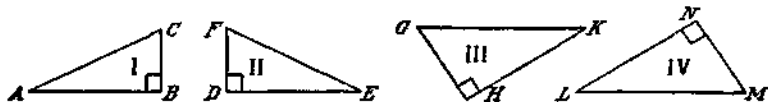
Example. To find $\tan 31^\circ$: follow the column under "Angle" until you reach 31° . You will find $\tan 31^\circ$ in the column under "Tan," opposite 31° . Thus, $\tan 31^\circ = .6009$, to four decimal places. This checks with our experiment.

Compare the values of $\tan 35^\circ$, $\tan 50^\circ$, and $\tan 60^\circ$, in the table, with the ratios found by experiment.

Use the table of tangents of angles to find the following:

- | | | |
|--------------------|--------------------|--------------------|
| a. $\tan 14^\circ$ | f. $\tan 4^\circ$ | k. $\tan 85^\circ$ |
| b. $\tan 39^\circ$ | g. $\tan 48^\circ$ | l. $\tan 44^\circ$ |
| c. $\tan 74^\circ$ | h. $\tan 29^\circ$ | m. $\tan 72^\circ$ |
| d. $\tan 45^\circ$ | i. $\tan 63^\circ$ | n. $\tan 19^\circ$ |
| e. $\tan 86^\circ$ | j. $\tan 37^\circ$ | o. $\tan 21^\circ$ |

A Study in Right Triangles.



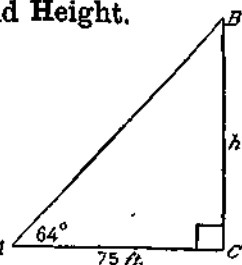
1. Name the hypotenuse in each right triangle shown above.
2. Name the arms in each triangle.
3. Name each acute angle by a single letter (vertex).
4. Name the opposite arm and the adjacent arm of each acute angle.
5. Which is the longest side in any right triangle; the largest angle? What is the sum of its two acute angles?

Table of Values of Trigonometric Ratios.

Angle	Sin	Cos	Tan	Angle	Sin	Cos	Tan
1°	.0175	.9998	.0175	46°	.7193	.6947	1.0355
2°	.0349	.9994	.0349	47°	.7314	.6820	1.0724
3°	.0523	.9986	.0524	48°	.7431	.6691	1.1106
4°	.0698	.9976	.0699	49°	.7547	.6561	1.1504
5°	.0872	.9962	.0875	50°	.7660	.6428	1.1918
6°	.1045	.9945	.1051	51°	.7771	.6293	1.2349
7°	.1219	.9925	.1228	52°	.7880	.6157	1.2799
8°	.1392	.9903	.1405	53°	.7986	.6018	1.3270
9°	.1564	.9877	.1584	54°	.8090	.5878	1.3764
10°	.1736	.9848	.1763	55°	.8192	.5736	1.4281
11°	.1908	.9816	.1944	56°	.8290	.5592	1.4826
12°	.2079	.9781	.2126	57°	.8387	.5446	1.5399
13°	.2250	.9744	.2309	58°	.8480	.5299	1.6003
14°	.2419	.9703	.2493	59°	.8572	.5150	1.6643
15°	.2588	.9659	.2679	60°	.8660	.5000	1.7321
16°	.2756	.9613	.2867	61°	.8746	.4848	1.8040
17°	.2924	.9563	.3057	62°	.8829	.4695	1.8807
18°	.3090	.9511	.3249	63°	.8910	.4540	1.9626
19°	.3256	.9455	.3443	64°	.8988	.4384	2.0503
20°	.3420	.9397	.3640	65°	.9063	.4226	2.1445
21°	.3584	.9336	.3839	66°	.9135	.4067	2.2460
22°	.3746	.9272	.4040	67°	.9205	.3907	2.3559
23°	.3907	.9205	.4245	68°	.9272	.3746	2.4751
24°	.4067	.9135	.4452	69°	.9336	.3584	2.6051
25°	.4226	.9063	.4663	70°	.9397	.3420	2.7475
26°	.4384	.8988	.4877	71°	.9455	.3256	2.9042
27°	.4540	.8910	.5095	72°	.9511	.3090	3.0777
28°	.4695	.8829	.5317	73°	.9563	.2924	3.2709
29°	.4848	.8746	.5543	74°	.9613	.2756	3.4874
30°	.5000	.8660	.5774	75°	.9659	.2588	3.7321
31°	.5150	.8572	.6009	76°	.9703	.2419	4.0108
32°	.5299	.8480	.6249	77°	.9744	.2250	4.3315
33°	.5446	.8387	.6494	78°	.9781	.2079	4.7046
34°	.5592	.8290	.6745	79°	.9816	.1908	5.1446
35°	.5736	.8192	.7002	80°	.9848	.1736	5.6713
36°	.5878	.8090	.7265	81°	.9877	.1564	6.3138
37°	.6018	.7986	.7536	82°	.9903	.1392	7.1154
38°	.6157	.7880	.7813	83°	.9925	.1219	8.1443
39°	.6293	.7771	.8098	84°	.9945	.1045	9.5144
40°	.6428	.7660	.8391	85°	.9962	.0872	11.4301
41°	.6561	.7547	.8693	86°	.9976	.0698	14.3007
42°	.6691	.7431	.9004	87°	.9986	.0523	19.0811
43°	.6820	.7314	.9325	88°	.9994	.0349	28.6363
44°	.6947	.7193	.9657	89°	.9998	.0175	57.2900
45°	.7071	.7071	1.0000				

Using the Tangent of an Angle to Find Height.

Problem: Find the height of a tree, BC in the figure at the right, from the following measurements: angle A = 64° ; AC = 75 feet.



A. Solution by scale drawing. A diagram can be drawn to scale on squared paper, with the measurements 64° for angle A, 75' for length AC, and 90° for angle C.

The scale length of the height BC can be measured on the completed right triangle, and then converted to actual length by use of the scale.

Suppose you use the scale 1 space = 20 ft. A slight inaccuracy in the drawing of the triangle can easily be caused by a number of factors, such as the manner of use of the ruler or protractor, or a lack of precision in the instrument itself. A difference of one-half space in the length of BC in the drawing will result in an error of 10 feet. If the scale 1 space = 30 ft. is used, the mistake may be even greater.

B. Solution by trigonometric ratio. A solution of the problem by means of tangent of an angle will produce a more accurate result than one by scale drawing, assuming the same precision in actual measurement in both cases.

SAMPLE PLAN AND METHOD:

Angle A = 64°

Opp. arm BC = h

Adj. arm AC = 75'

$$(1) \tan. \text{ of angle} = \frac{\text{opp. arm}}{\text{adj. arm}}$$

$$(2) \tan 64^\circ = 2.0503$$

$$(3) \frac{2.0503}{1} = \frac{h}{75}$$

$$(4) 1 \times h = 2.0503 \times 75$$

$$(5) h = 153.7725$$

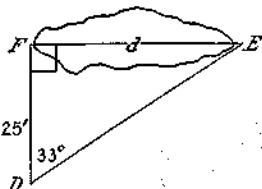
Answer: Height of tree is 154 ft., to the nearest unit.

Notes of explanation: A diagram should always be used. From the location of the acute angle, determine the opposite arm and the adjacent arm. The tangent of the angle is found in the table on page 109 (step 2). This tangent is the value of the ratio of the opposite arm to the adjacent arm (step 3). The number 1 is placed under the 2.0503 as an aid in the use of rule that the product of the means equals the product of the extremes (step 4). For practical farm

work, round off to the whole unit, using the first decimal place for this purpose.

Using Trigonometry to Find Distance.

Problem: The distance across a swamp EF is found by indirect measurement. DF is a base line of 125 feet laid out at an angle of 90° to EF (angle F = 90°). Angle FDE measure 33° . Find the distance EF across the swamp.



Solution:

$$\text{Angle } D = 33^\circ$$

$$\text{Opp. arm } EF = d$$

$$\text{Adj. arm } DF = 125'$$

$$(1) \tan \text{ of Angle} = \frac{\text{opp. arm}}{\text{adj. arm}}$$

$$(2) \tan 33^\circ = .6494$$

$$(3) \frac{.6494}{1} = \frac{d}{125}$$

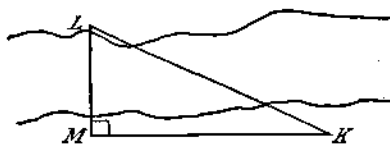
$$(4) 1 \times d = .6494 \times 125$$

$$(5) d = 81.175$$

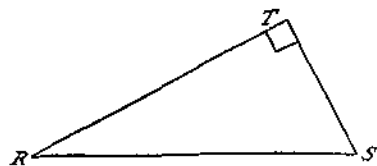
Answer: Distance across swamp is 81 ft., (nearest unit).

Practice in the Use of Tangent of an Angle.

1. Find the height of a tree, if the angle of elevation of its top is 46° , measured 100' from the foot of the tree.
2. At a distance 50' from the foot of a tree, the angle of elevation of the top is 51° . How high is the tree?
3. The angle of elevation of the top of a silo is 72° , when measured at a distance of 30 feet from the foot of the silo. What is the height of the silo?
4. A ladder is leaning against a building. The distance from the foot of the ladder to the foot of the building is 22 feet, and the angle between the ladder and the ground is 53° . To what height on the building does the ladder reach?
5. A steel cable used as a support for a pole makes an angle of 67° with the ground at a point 18 feet from the foot of the pole. Find the height of the pole.



6. To find the width of a river by taking all measurement on one side, a rock L on the other side is sighted. MK is a baseline of 250'; angle M = 90°; and angle K = 32°. Find the width ML.



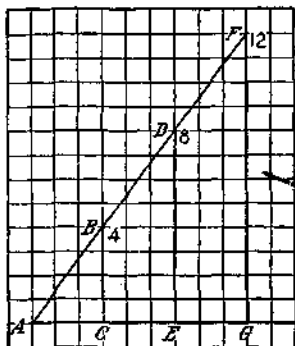
7. Find the width TS of a deep gorge. The measurements taken are: base line

RT = 75'; angle T = 90°; and angle R = 41°.

Sine of an Angle.*

The ratio tangent involves only the two arms of a right triangle. Some other ratio must be used for indirect measurement involving the hypotenuse. We will try another experiment with right triangles.

Draw an angle of 53° on squared paper. Erect perpendiculars at 3, 6 and 9 units respectively, from the vertex A of the angle. Right triangles ABC, ADE and AFG are formed. Observe the ratio of the arm opposite angle A to the hypotenuse in each triangle. Count the number of units in the arm, and measure the number of units in the hypotenuse with a strip of squared paper as a ruler.



In triangle ABC,

$$\frac{BC}{AB} = \frac{4}{5} = .8$$

In triangle ADE,

$$\frac{DE}{AD} = \frac{8}{10} = .8$$

In triangle AFG,

$$\frac{FG}{AF} = \frac{12}{15} = .8$$

The ratio of the arm opposite the acute angle 53° in any right triangle to the hypotenuse always has the same fixed

* The study of sine of an angle is optional.

value, .8, to the nearest tenth. This ratio is called the **sine of an angle**. An experiment such as used for the tangent of an angle, on page 107, would easily show that the sine is greater for larger angles. The table on page 109, has the values of the sines of angles from 1° to 89° under the column headed "Sin" (abbreviation for sine).

RULE 25. For an acute angle **A** in a right triangle,

sine of angle **A** = $\frac{\text{the arm opposite angle A}}{\text{the hypotenuse of the triangle}}$

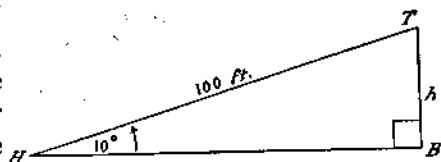
$$\text{FORMULA: } \sin A = \frac{\text{opp. arm}}{\text{hyp.}}$$

Find the following in the table of sines of angles:

- | | | |
|--------------------|--------------------|--------------------|
| a. $\sin 31^\circ$ | f. $\sin 30^\circ$ | k. $\sin 42^\circ$ |
| b. $\sin 84^\circ$ | g. $\sin 75^\circ$ | l. $\sin 18^\circ$ |
| c. $\sin 15^\circ$ | h. $\sin 57^\circ$ | m. $\sin 83^\circ$ |
| d. $\sin 27^\circ$ | i. $\sin 69^\circ$ | n. $\sin 54^\circ$ |
| e. $\sin 46^\circ$ | j. $\sin 22^\circ$ | o. $\sin 66^\circ$ |

Using the Sine of an Angle.

Problem: The slope of a road is about 10° . What vertical distance does the road rise for every 100 ft. along the road?



SAMPLE PLAN

and

METHOD:

Angle $H = 10^\circ$

BT is opp. arm.

BT = h

HT is the hyp.

HT = 100'

$$(1) \sin \text{ of angle} = \frac{\text{opp. arm}}{\text{hyp.}}$$

$$(2) \sin \text{ of } 10^\circ = .1736$$

$$(3) \frac{.1736}{1} = \frac{h}{100}$$

$$(4) 1 \times h = .1736 \times 100$$

$$(5) h = 17.36$$

Answer: Road rises 17 ft. (nearest unit).

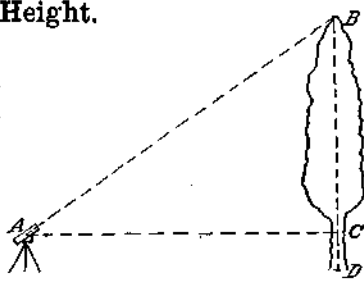
Note: In solving for a side of a right triangle by trigonometry, it is necessary to select the proper ratio, that is, tangent or sine. One side and an angle are given, and another side must be found. If the two sides used in the problem are arms, you solve by tangent. If the hypotenuse and the arm opposite the given angle are used in the problem, solve by sine. This is the case in the above problem. If the hypotenuse and adjacent arm are in the problem, there is a third ratio, the cosine. However, sine can also be used in such an example, if the other acute angle in the right triangle is found by subtracting the known angle from 90° . The adjacent arm of one acute angle then becomes the opposite arm of the other acute angle.

Solve these problems by using sine of an angle:

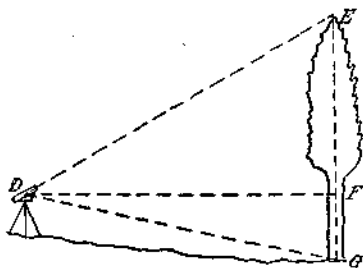
1. Find the vertical rise for 200 ft. of a road, which has a slope of about 12° .
2. How high on a building will a 30-foot ladder reach, if the angle between the ladder and the ground is 70° ?
3. A 52-foot steel cable is used as a support for a pole. If the angle between the cable and the ground is 58° , find the height of the pole.

The Actual Measurement of Height.

In actual measurement of height, the sights of the instrument used to measure the angle of elevation are rarely in line with the foot of the tree. Therefore, only length BC is found by means of the tangent of angle CAB. CD, which is called the



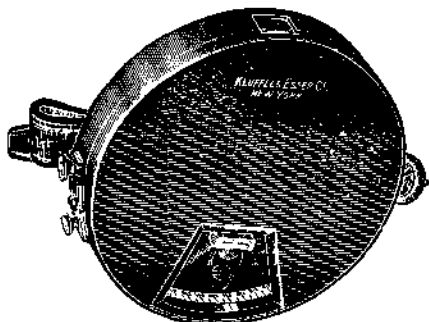
height of the instrument, must be measured and added to BC, for the total height of the tree.



The complete height of a tree can be found in another way. Measure the angle of elevation (angle FDE) and the angle of depression (angle FDG)

from the same point D, at a certain distance from the tree. Compute EF by tangent of angle FDE in triangle DEF, and find FG by tangent of angle FDG in triangle DFG. Add EF and FG.

The box hypsometer is an instrument that greatly simplifies the calculation of the height of a tree. The instrument is sighted in turn at the top and at the bottom of the tree, at a convenient distance from the tree. Instead of reading in angles, the instrument shows the tangent of the angle. For



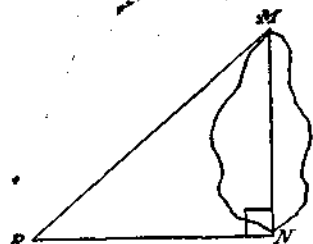
Hypsometer and Grademeter.
Courtesy of Kuffel & Esser Co.

example, when standing 100 feet from the tree, the pendulum points to 65 in sighting the top of the tree, and 10, in sighting the bottom. Thus, the tree is $.65 \times 100$, or 65 feet, above the level of the instrument; and $.10 \times 100$, or 10 feet, below its level. The total height of the tree is the sum of these two amounts, 75 feet. The instrument shown on page 99 indicates directly the height of the tree above and below eye level.

Projects in Indirect Measurement by Trigonometry.

- I. The height of a tree (See Fig. 1 on page 114).
 - (a) Estimate the height of a certain tree.
 - (b) Measure a base line of 80 feet horizontally from the foot of the tree.
 - (c) At the end of this base line, sight horizontally with an instrument for the measurement of vertical angles. Place a mark on the tree in line with the sights, and measure with tape the length of the tree below this point to the ground.
 - (d) Sight the top of the tree, and read the angle of elevation.
 - (e) Calculate by tangent the height of the tree above the mark of (c). What is the full height?

- (f) Repeat this method to find the height of this same tree, using a base line of 100 feet. Compare the heights obtained. Compare with your estimate.
- II. The height of a structure (See Fig. 2 on page 114).
- Estimate the height of the building.
 - Measure a base line of 70 feet horizontally from the foot of the building.
 - At the end of this line, sight the top of the building, and read the angle of elevation.
 - From the same point, sight the bottom of the building, and read the angle of depression.
 - Calculate by tangent the height of the building above and below the level of the instrument.
 - What is the total height of the building?
 - Repeat this method to find the height of the same building, using a base line of 90 feet. Compare the heights obtained. Compare with your estimate.
- III. To find an "inaccessible" distance MN:
- Measure a base line RN at right angles to MN.
 - Measure angle NRM.
 - Calculate MN by means of the tangent of angle NRM.
 - Measure MN with a steel tape. Compare with the result in (c).



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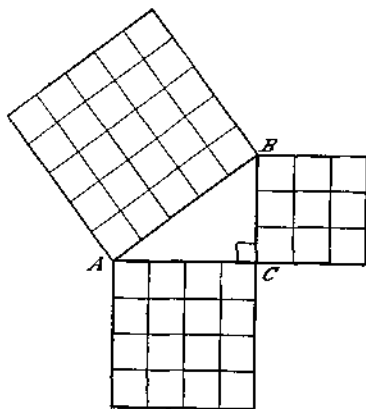
Chapter XI

THE RULE OF THE RIGHT TRIANGLE

ONE of the oldest discoveries in mathematical knowledge is the **Pythagorean theorem**. This rule is named after Pythagoras, a Greek, who lived almost 2500 years ago. Even mathematicians before his time made use of this important principle. We shall learn the rule of the right triangle, and its application to indirect measurement.

The problem to be solved by the rule of the right triangle is to find the length of the hypotenuse of a right triangle, if the two arms of the triangle are known.

Triangle ABC is a right triangle, with its right angle at C. The arms are AC and BC, and the hypotenuse is AB. If you carefully construct this right triangle with AC 4 units long, and BC 3 units long, you will find by measurement that AB is exactly 5 units in length. What is the relation between these numbers 3, 4 and 5? You can see that the length of the hypotenuse is not equal to the sum of the lengths of the two arms.

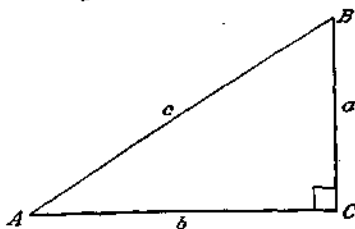


Construct a square on each arm of right triangle ABC, and on the hypotenuse, as shown in the diagram. Count the number of square units in each of the three squares. What is the relation between the numbers 9, 16 and 25? Now observe that the square on the hypotenuse does equal the sum of the

squares on the two arms. Is this true for every right triangle? Mathematical proof does establish this fact.

RULE 26. The rule of the right triangle.

The square on the hypotenuse of a right triangle equals the sum of the squares on the two arms.



The standard lettering for a right triangle is ABC, where C is the vertex of the right angle, and A and B are the vertices of the acute angles. Small letters are used for the sides: the arms are a and b, and the hypotenuse is c. The letters a, b, and c are opposite the same capital letters. This notation is used in the following formula:

FORMULA for Rule 26.:

$$c^2 = a^2 + b^2.$$

Example. The arms of a right triangle are 6 and 8 units, respectively. Find the hypotenuse.

You can use Rule 26, without constructing the right triangle and drawing the squares on its sides. The area of the square on each arm equals the square of

the arm. The square on the hypotenuse c^2 equals the sum of a^2 and b^2 . As the area of the square on the hypotenuse equals 100 square units, the length of the hypotenuse, a side of the square, equals the square root of the area. Review squares and square roots in chapter IV.

Add:

$a = 6$	$a^2 = 36$
$b = 8$	$b^2 = 64$
	$c^2 = 100$
	$c = \sqrt{100} = 10.$

To summarize the method of using Rule 26:

- Square each arm of the right triangle.
- The square of the hypotenuse equals the sum of the squares of the arms.
- To find the length of the hypotenuse, extract the square root of the square of the hypotenuse.

Testing the rule of the right triangle.

	<i>a</i>	<i>b</i>	<i>c</i> by Rule 26	<i>c</i> by Meas- ure
1)	4	3		
2)	6	8		
3)	5	12		
4)	8	15		
5)	9	12		

Five right triangles are tabulated at the left. Calculate the number of units in the length of the hypotenuse of each triangle by means of Rule 26. To check the results, construct each right triangle. Use the lengths of the arms for the construction and measure the hypotenuse.

Finding the Length of an Arm of a Right Triangle.

The rule of the right triangle can also be used to find the length of an arm, when the length of the other arm and the hypotenuse are known. Consider the right triangle on page 117, having arms of 3 and 4 units respectively, and an hypotenuse of 5 units. The squares on the arms have areas of 9 and 16 square units; the area of the square on the hypotenuse is 25 square units. $9 = 25 - 16$, and $16 = 25 - 9$. Thus, the square on one arm of a right triangle equals the difference between the squares on the hypotenuse and the other arm.

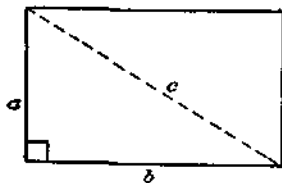
RULE 27. To find the length of an arm of a right triangle,

- (a) Square the other arm and subtract from the square of the hypotenuse.
- (b) Extract the square root of the difference.

$$\text{FORMULA: } a^2 = c^2 - b^2 \quad \text{or} \quad b^2 = c^2 - a^2$$

Practical Use of the Rule of the Right Triangle.

Example 1. What is the distance diagonally across a rectangular field, if its length and width are 16 and 12 rods, respectively.



SAMPLE PLANand
METHOD

$a = 12 \text{ rd.}$

$b = 16 \text{ rd.}$

Add:

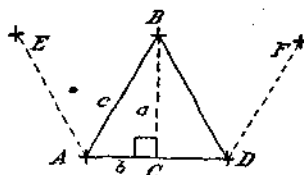
$a^2 = 144 \text{ sq. rd.}$

$b^2 = 256 \text{ sq. rd.}$

$c^2 = 400 \text{ sq. rd.}$

Answer: $c = \sqrt{400} = 20 \text{ rd.}$

Example 2. What is the distance between the rows of trees in an orchard planted in the equilateral triangle system, if the distance between the trees is 30 feet.



Triangle ABD is equilateral.

$AB = AD = BD = 30 \text{ feet. } AC = \frac{1}{2} AD = 15 \text{ feet.}$

Subtract:

$c = 30' \quad c^2 = 900 \text{ sq. ft.}$

$b = 15' \quad b^2 = 225 \text{ sq. ft.}$

$a^2 = 675 \text{ sq. ft.}$

$a = \sqrt{675} = 25.98 \text{ ft.}$

Extract the square root of 675, by the method on page 44.

Answer: The distance is 26.0 ft. to the nearest tenth.

Solve these problems by the rule of the right triangle:Draw a diagram for each, and label the sides a , b , and c .

1. A new road is built cutting diagonally across two roads which meet at right angles. $BC = 80$ rods, and $AC = 150$ rods.

(a) Find the length of road AB.

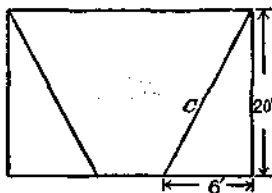
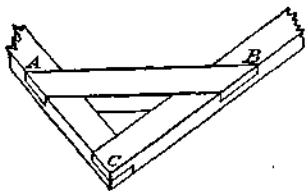
(b) What distance is saved by using the new road from A to B, instead of going from A to C, and then from C to B?

2. A ladder stands with its base 7 feet from the foot of a building, and its top reaches a window 24 feet above the level of the ground. How long is the ladder?

3. A rectangular room is 31 feet long by 19 feet wide. What

is the diagonal distance across the room? Answer to the nearest tenth of a foot.

4. AB is a corner brace used in the construction of a granary. A and B, the ends of the brace, are each 3 feet from the corner C. How long is AB (nearest tenth of a ft.)?



5. At the left is shown part of the cross-section of a cigar wrapper tobacco curing barn. Find the length of the slanting cross-piece (nearest tenth of a foot), which extends from a height of 20 feet to a point 6 feet from the corner of the barn.

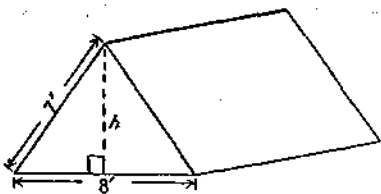
6. A field has the shape of a right triangle. Its base is 15 rods, and the hypotenuse is 39 rods. Find the height.

7. The hypotenuse of a field having the shape of a right triangle is 30 rods, and its height is 24 rods. Find the length of the base.

8. The end of a portable hog house is 8 feet wide at the bottom, and the slope of the roof is 7 feet long.

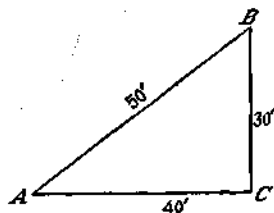
(a) Find the height of the house, to the nearest tenth of a foot.

(b) What is the area of the end?



9. Find the distance (to the nearest tenth of a foot) between the rows of trees in an orchard planted in the hexagonal system, if the distance between the trees is 20 feet.

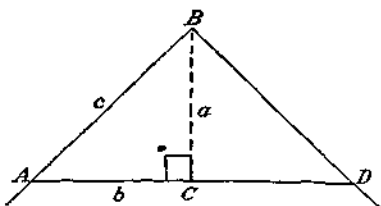
10. The following method is used to lay out a right angle: Use a base line of 40 feet. Hold one end of a tape at point A, and the end of 80 feet at point C. Stretch



out the tape, and find point B at the end of 50 feet from A. Prove that angle C is 90° .

Roof Measurement.

The end of a roof (gable) is shown in the figure. The width AD is called the **span**. The slanting piece of lumber from B to A or from B to D, and running a short distance past these points, is a **rafter**. BC is the rise of the rafter, or height of the peak.



The **pitch** of the roof is the height divided by the span. If BC is $\frac{1}{3}$ of AD, the pitch is $\frac{1}{3}$. If the pitch is $\frac{1}{4}$, AD is 4 times BC, or BC is $\frac{1}{4}$ of AD.

To find the length of the rafter, use triangle ABC and the rule of the right triangle. In actual practice, allowance must be made for the extension of the rafter beyond the edge of the roof, and for the fit of the rafter at the top.

Example. The span of a poultry house is 10 feet. What length rafter must be used if the roof is given a pitch of one-fourth?

In the above figure of a roof, $AC = \frac{1}{2} AD$. As the pitch is $\frac{1}{4}$, $BC = \frac{1}{4} AD$.

Add:

$$BC = a = \frac{1}{4} \times 10 = 2.5'$$

$$AC = b = \frac{1}{2} \times 10 = 5'$$

$$a^2 = 6.25 \text{ sq. ft.}$$

$$b^2 = 25.00 \text{ sq. ft.}$$

$$c^2 = 31.25 \text{ sq. ft.}$$

$$c = \sqrt{31.25} = 5.59 + \text{ft.}$$

Answer to the nearest tenth of a foot: 5.6 feet.

Find the lengths of the rafters for the following roofs:

1. Pitch = $\frac{1}{3}$, span = 24 feet.
2. Pitch = $\frac{1}{2}$, span = 20 feet.
3. Pitch = $\frac{1}{6}$, span = 36 feet.
4. Pitch = $\frac{1}{8}$, span = 28 feet.
5. Pitch = $\frac{1}{4}$, span = 30 feet.

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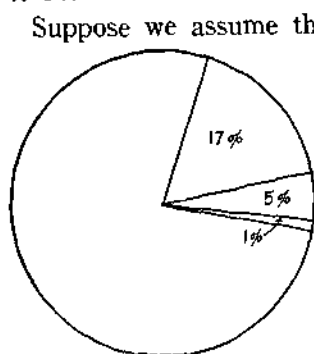
Suggestions on Planting Orchards, by R. E. Marshall. (See References, Chap. V.)

Chapter XII

REVIEW OF PERCENTAGE

MANY uses of percentage appear in farming. Ordinary business transactions, and actual farm work such as dairying, animal feeding, and fertilizing, require a knowledge of per cents. The following review in percentage will greatly assist you in the remaining chapters of this book.

What Per Cent Means.



Hundredth Parts

Suppose we assume that a circle is 1 whole unit. If we divide this circle into 100 parts, then one part (shown in the diagram) is $\frac{1}{100}$ part of the unit. $\frac{1}{100}$ part of an entire quantity is called 1 per cent, and written in abbreviated form is 1%. Thus 1 per cent means one part out of 100. As $\frac{1}{100}$ is equivalent to the decimal .01, 1% equals .01.

In the same way, 5 per cent means 5 parts out of 100, and is equivalent to the decimal .05; 17% means $\frac{17}{100}$, and equals .17. Also, 100 per cent means all 100 parts, that is, the entire amount.

Writing Per Cents as Decimals, and Decimals as Per Cents.

- (1) $8\% = .08$, because 8 per cent is $\frac{8}{100}$.
- (2) $37\% = .37$, because 37 per cent is $\frac{37}{100}$.
- (3) $4\frac{1}{4}\% = .0425$, because $4\frac{1}{4}$ per cent is $\frac{4.25}{100}$.
- (4) $.04 = 4\%$, because 4 per cent is $\frac{4}{100}$.

(5) $.872 = 87.2\%$, because 87.2 per cent is $87.2/100$.

(6) $.0063 = .63\%$, because $.63\%$ is $.63/100$.

RULE 28.

(a) To write a per cent as a decimal, move the decimal point two places to the left.

(b) To write a decimal as a per cent, move the decimal point two places to the right.

Write the following per cents as decimals:

- | | | | |
|--------|-----------|-----------|-----------------------|
| 1. 26% | 6. 31.2% | 11. .5% | 16. .024% |
| 2. 46% | 7. 46.8% | 12. .8% | 17. $26\frac{1}{2}\%$ |
| 3. 53% | 8. 93.1% | 13. .51% | 18. $38\frac{1}{4}\%$ |
| 4. 7% | 9. 9.24% | 14. .23% | 19. $6\frac{1}{2}\%$ |
| 5. 3% | 10. 3.72% | 15. .016% | 20. $2\frac{3}{4}\%$ |

Write the following decimals as per cents:

- | | | | |
|---------|----------|-----------|-----------|
| 21. .38 | 26. .153 | 31. .093 | 36. .0008 |
| 22. .57 | 27. .684 | 32. .006 | 37. .365 |
| 23. .81 | 28. .317 | 33. .0012 | 38. .4225 |
| 24. .06 | 29. .082 | 34. .0048 | 39. .035 |
| 25. .08 | 30. .063 | 35. .0843 | 40. .0425 |

The Equivalent Per Cents of Common Fractions.

Per cents are often used in place of fractions. On the other hand, a computation is frequently shortened by the use of a fraction instead of a per cent. Consider again the circle divided into 100 parts, or 100 per cents. A fraction of the whole circle, such as $\frac{1}{4}$, equals that part of 100%, or 25%; $\frac{1}{8}$ equals $\frac{1}{8} \times 100\%$, or $12\frac{1}{2}\%$.

Example. $\frac{3}{4} = \frac{3}{4} \times 100\% = 300/4\% = 42\frac{1}{2}\%$.

Change each of these fractions to a per cent:

- | | | | |
|--------------------|--------------------|---------------------|--------------------|
| 41. $\frac{1}{13}$ | 45. $\frac{1}{60}$ | 49. $\frac{11}{20}$ | 53. $\frac{5}{16}$ |
| 42. $\frac{1}{21}$ | 46. $\frac{1}{40}$ | 50. $\frac{13}{20}$ | 54. $\frac{7}{16}$ |
| 43. $\frac{1}{17}$ | 47. $\frac{1}{80}$ | 51. $\frac{16}{20}$ | 55. $\frac{5}{12}$ |
| 44. $\frac{1}{18}$ | 48. $\frac{1}{45}$ | 52. $\frac{17}{20}$ | 56. $\frac{7}{12}$ |

$\frac{1}{2} = 50\%$	$\frac{1}{6} = 16\frac{2}{3}\%$	$\frac{3}{10} = 30\%$	$\frac{1}{14} = 7\frac{1}{7}\%$
$\frac{1}{4} = 25\%$	$\frac{5}{6} = 83\frac{1}{3}\%$	$\frac{1}{20} = 5\%$	$\frac{1}{15} = 6\frac{2}{3}\%$
$\frac{3}{4} = 75\%$	$\frac{1}{8} = 12\frac{1}{2}\%$	$\frac{3}{20} = 15\%$	$\frac{1}{16} = 6\frac{1}{4}\%$
$\frac{1}{3} = 33\frac{1}{3}\%$	$\frac{3}{8} = 37\frac{1}{2}\%$	$\frac{7}{20} = 35\%$	$\frac{1}{25} = 4\%$
$\frac{2}{3} = 66\frac{2}{3}\%$	$\frac{5}{8} = 62\frac{1}{2}\%$	$\frac{9}{20} = 45\%$	$\frac{2}{25} = 8\%$
$\frac{1}{5} = 20\%$	$\frac{7}{8} = 87\frac{1}{2}\%$	$\frac{1}{7} = 14\frac{2}{7}\%$	$\frac{1}{30} = 3\frac{1}{3}\%$
$\frac{2}{5} = 40\%$	$\frac{1}{10} = 10\%$	$\frac{1}{9} = 11\frac{1}{9}\%$	$\frac{1}{40} = 2\frac{1}{2}\%$
$\frac{3}{5} = 60\%$	$\frac{3}{10} = 30\%$	$\frac{1}{11} = 9\frac{1}{11}\%$	$\frac{3}{40} = 7\frac{1}{2}\%$
$\frac{4}{5} = 80\%$	$\frac{7}{10} = 70\%$	$\frac{1}{12} = 8\frac{1}{3}\%$	$\frac{1}{50} = 2\%$

The **base** is a number, of which we want to find a certain per cent. The base consists of 100%.

The **rate** is the per cent or number of hundredth parts of the base to be taken.

Percentage is the product of the base multiplied by the rate. It is that part of the base represented by the number of per cents or hundredths in the rate.

The amount of butterfat in a certain quantity of milk is 4.2% of the milk. How much butterfat is there in 128 pounds of this milk?

Solution: 4.2% of 128 means $\frac{4.2}{100} \times 128$. However, it is more convenient to multiply by the decimal equivalent 0.042 * $128 \times .042 = 5.376$ pounds.

RULE 29. To find a certain per cent of a number, multiply the number by the per cent expressed as a decimal or as a convenient fraction.

FORMULA: $P = BR$ P = percentage
 B = base
 R = rate

* The 0 shows that there is no number in front of the decimal.

Practice in Computing Percentages.

1. Find 75.4% of \$65.

SAMPLE PLAN	$B = \$65$	$P = BR$
and	$R = 75.4\%, \text{ or } .754$	$P = 65 \times .754 =$
METHOD		49.010
		Answer: \$49.01

2. Find
- $16\frac{2}{3}\%$
- of 379 bushels.

SAMPLE PLAN	$B = 379 \text{ bu.}$	$P = BR$
and	$R = 16\frac{2}{3}\%, \text{ or } \frac{1}{6}$	$P = 379 \times \frac{1}{6} =$
METHOD		Answer: $63\frac{1}{6} \text{ bu.}$

Find these percentages:

- | | |
|---------------------------------|----------------------------------|
| 1. 28% of 38 lb. | 10. $14\frac{2}{7}\%$ of \$84.21 |
| 2. 32% of 498 gal. | 11. $62\frac{1}{2}\%$ of 72 tons |
| 3. 6% of 83 bu. | 12. $83\frac{1}{3}\%$ of 132 lb. |
| 4. 7% of 573 lb. | 13. 34.6% of 56 bu. |
| 5. 3.8% of 73 qt. | 14. 81.4% of 27 tons |
| 6. 4.97% of 275 lb. | 15. 0.14% of 345 qt. |
| 7. $12\frac{1}{2}\%$ of \$96. | 16. 0.038% of 460 lb. |
| 8. $8\frac{1}{3}\%$ of \$150. | 17. 0.008% of 800 qt. |
| 9. $66\frac{2}{3}\%$ of \$92.10 | 18. 0.009% of 900 lb. |

PERCENTAGE PROBLEM: Type II.

A farm of 150 acres has 24 acres of woodland. What per cent of the farm is woodland?

Solution: Per cent represents a fractional part of the base.

24 is $\frac{24}{150}$ of 150. This fraction reduces to $\frac{4}{25}$, which is equivalent to 16%.

$\frac{4}{25}$ can be reduced to per cent in another way. Divide 4.00 by 25; the quotient .16 equals 16%.

RULE 30. To find what per cent one number is of another, find what fractional part the first is of the second, and reduce this fraction to per cent.

FORMULA: $R = \frac{P}{B}$

Practice in Finding What Per Cent One Number is of Another.

1. 90 acres is what per cent of 210 acres?

SAMPLE PLANand
METHOD

$$\begin{aligned} P &= 90 \text{ A} \\ B &= 210 \text{ A} \end{aligned}$$

$$R = \frac{P}{B}$$

Divide:

$$R = \frac{90}{210} = \frac{3}{7} = \frac{.42\frac{6}{7}}{3.00}$$

Answer: $42\frac{6}{7}\%$

2. 45 lb. is what per cent of 250 lb.?
3. 28 acres is what per cent of 80 acres?
4. 22.5 bu. is what per cent of 300 bu.?
5. \$8 is what per cent of \$36.?
6. \$22 is what per cent of \$32.?
7. 4 tons is what per cent of 14 tons?
8. 48 acres is what per cent of 54 acres?

Find the following to the nearest tenth of a per cent:

9. What per cent of 624 quarts is 97 quarts.

SAMPLE PLANand
METHOD:

$$\begin{aligned} P &= 97 \text{ qt.} \\ B &= 624 \text{ qt.} \end{aligned}$$

$$R = \frac{P}{B}$$

Divide:

$$R = \frac{97}{624} = \frac{.1554+}{97.0000}$$

Answer: 15.5%

10. What per cent of \$95 is \$36?
11. What per cent of 640 eggs is 33 eggs?
12. What per cent of 51 gallons is 8 gallons?
13. What per cent of 87 feet is 6.4 feet?
14. What per cent of 116 pounds is 13.26 pounds?
15. What per cent of 19 tons is $3\frac{1}{4}$ tons?

PERCENTAGE PROBLEM: Type III.

If it took 12 hours of work to plow 24% of the land on a farm, how long should the entire job take?

Solution: As 24% of the base (the total time) is 12, 1% of the base equals $\frac{1}{24}$ of 12. The base or 100%, equals $100 \times \frac{1}{24}$ of 12. This is equivalent to $12 \times \frac{100}{24}$. Thus, 12 is divided by $\frac{24}{100}$, or 24%.

If the per cent does not reduce to a convenient fractional equivalent, divide by the decimal equivalent. Then, $12 \div .24$ equals 50 hours.

Check: 24% of 50 hr. = 12 hr.

RULE 31. To find a number when a certain per cent of it is given, divide the number by the fractional or decimal equivalent of the per cent.

$$\text{FORMULA:} \quad B = \frac{P}{R}$$

Note: The formulas for Type II, and Type III, percentage problems, can be found by algebra. The equation for percentage problem, Type I, is $P = BR$. If this equation is solved for the letter B by the method on page 103, the result is: $B = P/R$; when solved for R, the result is: $R = P/B$. The fact that P is the numerator in both formulas should make it easier for you to remember them.

Practice in Finding a Number if a Certain % of it is Given.

1. Find the quantity of which 15.6 lb. is 15%.

SAMPLE PLAN

and
METHOD

$$\begin{aligned} P &= 15.6 \text{ lb.} \\ R &= 15\%, \text{ or } .15 \end{aligned}$$

$$\begin{aligned} B &= \frac{P}{R} && \text{Divide: *} \\ B &= \frac{15.6}{.15} && \frac{104.}{\underline{15.60.}} \end{aligned}$$

Answer: 104 lb. Check: 15% of 104 lb. = 15.6 lb.

2. 11 quarts is 20% of what amount?
3. 28 acres is 35% of what amount?
4. 22.5 pounds is 18% of what amount?
5. 28.8 bushels is 45% of what amount?

* 6. Work out Special Drill No. 10, on page 275, in division of decimals.

Find the following to the nearest whole number:

7. Of what quantity is 87 tons 42%?
8. Of what quantity is 96 acres 53%?
9. Of what quantity is 1562 pounds 19.2%?
10. Of what quantity is 371 quarts 4.5%?

General Review of Percentage Problems.

1. A farmer buys \$182 worth of supplies from a store that gives a discount (reduction) of 3% if the bill is paid within 15 days. What is the net bill, if paid within 15 days?
2. An agent charges 5% commission for selling a farm for \$7500. What is the amount the seller receives after paying the commission?
3. The tax rate for a certain year is 2.74%. How much taxes must be paid on property assessed at \$6500?
4. What is the premium on a fire insurance policy covering property valued at \$3200, if the insurance rate is 0.5%?
5. If the dressing percentage of a hog is 75% of its live weight, find the value of a 240 pound hog, at 8 cents per pound, dressed weight.
6. Eggs which brought the farmer 24¢ a dozen in 1935 were finally sold to the consumer for 36¢. What per cent of the retail price did the farmer receive?
7. Of a total of 83,460 farmers in North Dakota in 1934, 32,656 were farm tenants. Find what per cent (to the nearest tenth) of the total number of farmers were tenants.
8. A certain milk is 4% butterfat. How much of this milk will supply 34.4 pounds of butterfat?
9. How much should be invested at a 5% return to yield an income of \$500 per year?
10. A certain farm yielded an average of 48 bushels of oats per acre in one year, and 54 bushels the next year. What was the per cent of increase?
11. If 26% of a fertilizer is the element Nitrogen, how many pounds of this fertilizer should be used to supply 540 pounds of Nitrogen. (Answer to the nearest whole number.)

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PART II

Chapter XIII

DAIRYING

DAIRYING is a very important branch of farming. Its products form a great part of the human food supply, and at the same time provide a steady source of income to the farmer. To make the business of dairying profitable, the farmer must be thoroughly familiar with all details of the production operations and the marketing transactions. With the aid of figures, he can compare the advantages of different dairy practices. Is he receiving the most return for his investment and labor, is the question he will be able to answer.

The Measurement of Milk.

Milk is usually measured by the quart or the pound. One quart of milk weighs 2.15 pounds. There are very slight variations in the weight of milk because of differences in its composition, and the use of 2.15 pounds as the weight of one quart of milk is reliable for practical purposes.

RULE 32. Conversion of quarts and pounds of milk.

- (a) To convert quarts of milk to pounds, multiply the number of quarts by 2.15.
- (b) To convert pounds of milk to quarts, divide the number of pounds by 2.15.

Note: For rough estimates, you may use 2 pounds as the weight of one quart of milk.

The weight of a quart of cream cannot be given a fixed value, because cream composition is too variable. The table at page 292 of the appendix gives the weight of a quart of cream for different compositions.



A Modern Dairy Barn.

Courtesy of H. E. Ross.

PRACTICE IN CONVERSION OF MEASUREMENTS OF MILK

1. **SAMPLE METHOD** for converting quarts of milk to pounds.

850 quarts of milk equal how many pounds?

By Rule 32, multiply 850 by 2.15.

$850 \times 2.15 = 1827.5$ lb. *Answer **

Change the following quantities of milk to pounds:

2. 55 quarts

4. 714 quarts

3. 164 quarts

5. 582 quarts

* Pages 269 to 276 in the appendix, contain a number of arithmetic drills. If you are in need of practice in decimals, work out Special Drills numbers 8, 9 and 10.

- | | |
|----------------|------------------|
| 6. 824 quarts | 9. 587.5 quarts |
| 7. 92.5 quarts | 10. 361.5 quarts |
| 8. 36.5 quarts | 11. 733.5 quarts |

12. SAMPLE METHOD for converting pounds of milk to quarts.

975 pounds of milk equal how many quarts?

By rule 32, divide 975 by 2.15. The result can be carried out to the desired number of decimal places.

$$975 \div 2.15 = 453.48+, \text{ or } 453.5 \text{ qt., (nearest tenth)}$$

Change the following quantities of milk to quarts:

Find the answer to the nearest tenth of a quart.

- | | |
|-----------------|--------------------|
| 13. 46 pounds | 18. 743.8 pounds |
| 14. 83 pounds | 19. 853.9 pounds |
| 15. 46.3 pounds | 20. 764.2 pounds |
| 16. 93.6 pounds | 21. 1,792.4 pounds |
| 17. 34.7 pounds | 22. 2,369.1 pounds |

23. The best record for milk production by a Holstein-Friesian cow is held by the cow, Carnation Ormsby Butter King, who produced 38,607 pounds of milk in 365 days.

- What is the average number of pounds of milk per day produced by this cow (nearest tenth of a lb.)?
- How many quarts of milk per day is this amount (nearest tenth of a quart)?

24. Melba 15th of Darbalara, a Milking Shorthorn cow, holds the milk production record for cows of that breed. She produced 32,522 pounds of milk in 365 days.

- Find the average number of pounds of milk per day. Answer to the nearest tenth of a pound.
- What is the average number of quarts per day. Answer to the nearest tenth of a quart.

25. An Ayrshire, Ardgowan Valda, holds the milk production record for that breed, with a total of 31,156 pounds of milk for 365 days. Find the average number of pounds of milk per day, and the average number of quarts of milk per day (to the nearest tenth).

26. The average for all breeds, recorded in the 1937 Year-book of Agricultural Statistics, U. S. Department of Agriculture, is 7,977 pounds of milk per year. Change to quarts of milk per year (nearest tenth of a quart).

COMPOSITION OF DAIRY PRODUCTS.

Milk.

1. Compute the number of pounds of each constituent in 850 pounds of milk having the following composition, and check your answers by totalling the constituents:

Water	87.1%	Albumin	0.7%
Milkfat	3.9%	Milk sugar	5.1%
Casein	2.5%	Ash	0.7%

Note: The constituents of the milk in this problem can be classified under the following headings:

Water	87.1%
Milk solids	12.9%
Fat	3.9%
Milk solids not fat (MSNF)	9.0%
Protein	3.2%
Casein	2.5%
Albumin	0.7%
Carbohydrate (milk sugar)	5.1%
Inorganic matter	0.7%

2. Compute the number of pounds of each constituent in 640 pounds of milk having the following composition, and check your total answer:

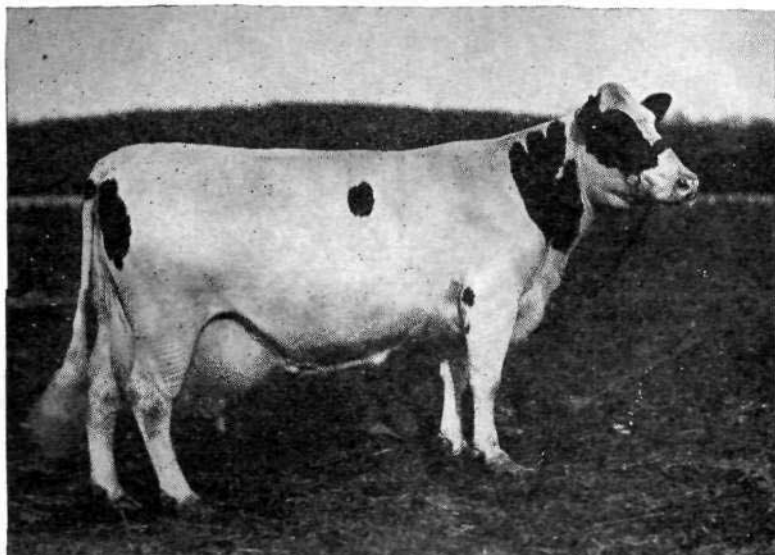
Water	88.0%	Albumin	0.5%
Milkfat	3.5%	Milk sugar	4.6%
Casein	2.7%	Ash	0.7%

Cream.

3. Compute the number of pounds of each constituent in 350 pounds of cream having the following composition, and

check your total answer: water, 54.6%; milkfat, 40%; milk solids not fat, 5.4%.

4. Find the weight of each constituent in 480 pounds of cream having the following composition, and check the total: water, 74%; milkfat, 18.5%; milk solids not fat, 7.5%.



Carnation Ormsby Butter King, Champion Milk and Butterfat Cow.

(See Problem 23, page 134).

Butter.

5. Determine the amount of each constituent in 150 pounds of the following butter, and check the total: water, 15.5%; milkfat, 81%; salt, 2.8%; and casein, 0.7%.

6. Find the weight of each constituent in 175 pounds of the following butter, and check the total: water, 13.9%; milkfat, 82.4%; solids not fat, 3.7%.

The Per Cent of Fat in Milk.

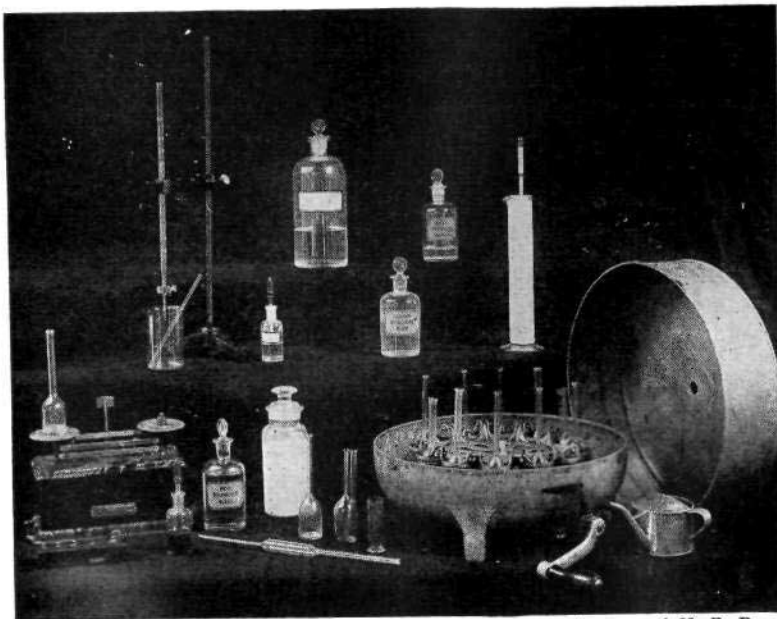
Fat is a very important ingredient of milk. Laws specify minimum milkfat content for milk sold for direct consump-

tion. Also, the quantity of a dairy product such as cream or butter that can be produced from milk depends upon the amount of fat in the milk. Prices paid to farmers for milk are often graded according to the per cent of milkfat (also called butterfat).

The fat content of milk is not the same for dairy cattle of different breeds. Milk from Jersey cows averages 5.3%, milkfat, the highest of all breeds. Guernsey milk is second, averaging about 5.0%. Individual cows within a breed vary in the fat percentage of their milk. Other factors may affect the richness of the milk of cows, as the season of the year, the manner of milking, and the care of the animal.

The Testing of Dairy Products.

The Babcock test, discovered by Dr. Babcock of Madison, Wisconsin, is a standard procedure for the determination of



Courtesy of H. E. Ross.

Apparatus for Testing Dairy Products.

the per cent of fat in a sample of milk or cream. This test can be used with slight variations for butter, skimmilk, buttermilk, and other dairy products. A dairyman can perform the test in little time with simple equipment.

Milkfat Problems.

The per cent of milkfat in any dairy product is called its test. The three percentage formulas are applicable to problems dealing with the test per cent of a dairy product. We will now rewrite the rules: the amount of milkfat (F) is the percentage; the amount of dairy product (D) is the base; and the test per cent (T) is the rate.

RULE 33. To find the amount of milkfat, the test per cent, or the amount of dairy product:

$$(a) \text{ Milkfat} = \text{Dairy product} \times \text{Test \%} \quad F = D T$$

$$(b) \text{ Test \%} = \text{Milkfat} \div \text{Dairy product} \quad T = F/D$$

$$(c) \text{ Dairy product} = \text{Milkfat} \div \text{Test \%} \quad D = F/T$$

Note: See the sample solutions of percentage problems on page 127, example 1, (Type I); page 128, example 9, (Type II); and page 129, example 1, (Type III).

Find the number of pounds of milkfat in the following dairy products:

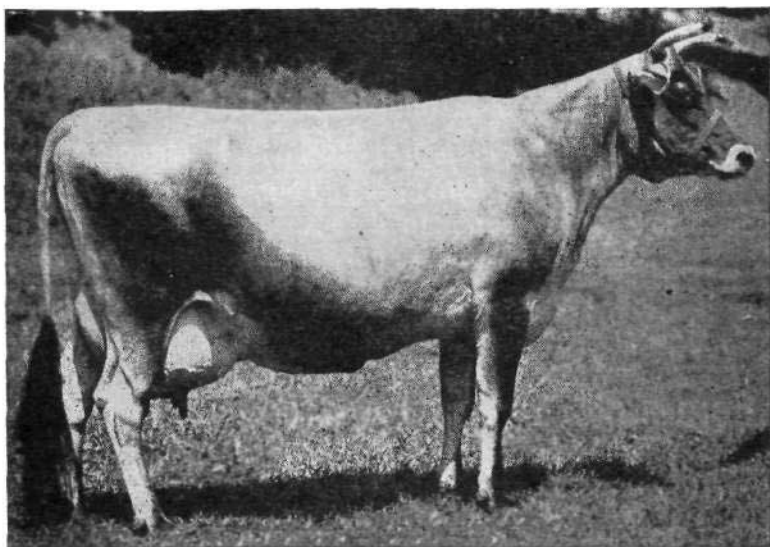
1. 840 lb. of milk, testing 3.7% milkfat;
2. 87.5 lb. of milk, testing 4.4% milkfat;
3. 365 lb. of cream, testing 38% milkfat;
4. 420 lb. of cream, testing 41.3% milkfat;
5. 850 lb. of buttermilk, testing 0.4% milkfat;
6. 640 lb. of buttermilk, testing 0.35% milkfat;
7. 720 lb. of skimmilk, testing 0.03% milkfat;
8. 695 lb. of skimmilk, testing 0.08% milkfat.

Find the tests of the following dairy products:

9. 300 lb. of milk, containing 12.6 lb. of milkfat;
10. 250 lb. of milk, containing 9.25 lb. of milkfat;
11. 340 lb. of cream, containing 71.4 lb. of milkfat;
12. 125 lb. of cream, containing 42.5 lb. of milkfat.

General butterfat problems:

13. How many pounds of 4.2% milk are needed to furnish 15.33 pounds of milkfat?
14. Find the number of quarts of 3.5% milk required to supply 29.4 quarts of milkfat?
15. How many pounds of 24% cream can be produced from milk containing 162 pounds of milkfat?



Stockwell's April Pogis of H. P., Champion Butterfat Producer of Jersey Breed.

(See Problem 16, this page.)

16. The record for butterfat (milkfat) production by a cow of Jersey breed is held by Stockwell's April Pogis of H. P. This cow in 365 days produced 17,880 pounds of milk having an average test of about 6.86%. Find to the nearest pound the total amount of milkfat produced by her during that period of time.

17. The record for butterfat production by cows of Guernsey breed is held by the cow Cathedral Rosalie. She produced

23,714.5 pounds of milk having an average test of about 5.115%, in 365 days. Find to the nearest pound the total quantity of milkfat produced by her in that period of time.

18. The champion cow of Brown Swiss breed is Illini Nellie. In 365 days, she produced 29,569.5 pounds of milk, containing 1,200.41 pounds of butterfat. Find the average test of her milk for the year, to the nearest tenth per cent.

19. If the average test of a certain cow's milk is 3%, find the total quantity of milk she would have to produce in one year, in order to supply 1245 pounds of butterfat.

20. How much 3.5% milk must a cow produce per day, to supply 1.75 pounds of butterfat a day? What would be the total quantity of milk in 365 days?

Finding the Weighted Average Test of the Milk of a Herd.

Problem: Compute the weighted average test of the milk of the following herd (nearest tenth of a per cent):

Cow A, 45 lb. of milk, testing 3.2% milkfat;

Cow B, 34 lb. of milk, testing 4.5% milkfat;

Cow C, 26 lb. of milk, testing 3.5% milkfat;

Cow D, 25 lb. of milk, testing 4.2% milkfat.

Solution:

Cow	Amount of milk	Test	Amount of milkfat
A	45 lb.	3.2%	$45 \times .032 = 1.44$ lb.
B	34 lb.	4.5%	$34 \times .045 = 1.53$ lb.
C	26 lb.	3.5%	$26 \times .035 = 0.91$ lb.
D	25 lb.	4.2%	$25 \times .042 = 1.05$ lb.
Totals	130 lb.		4.93 lb.

$$F = 4.93 \text{ lb.}$$

$$D = 130 \text{ lb.}$$

$$T = \frac{F}{D}$$

$$T = \frac{4.93}{130} = .0379$$

Answer: Test is 3.8%.

Note: It is incorrect to add the four tests, and then divide

by four, as the cows did not all produce the same quantity of milk.

Compute the weighted average test of the milk of the following herds (nearest tenth of a per cent):

1. Cow A, 50 lb. of milk, testing 3.1% milkfat;
Cow B, 30 lb. of milk, testing 3.6% milkfat;
Cow C, 20 lb. of milk, testing 3.7% milkfat.
2. Cow A, 42 lb. of milk, testing 3.5% milkfat;
Cow B, 35 lb. of milk, testing 4.2% milkfat;
Cow C, 25 lb. of milk, testing 3.4% milkfat;
Cow D, 27 lb. of milk, testing 4.0% milkfat.
3. Cow A, 36 lb. of milk, testing 3.2% milkfat;
Cow B, 29 lb. of milk, testing 4.5% milkfat;
Cow C, 18 lb. of milk, testing 3.9% milkfat;
Cow D, 37 lb. of milk, testing 4.1% milkfat;
Cow E, 43 lb. of milk, testing 3.5% milkfat.

The Production of Cream.

Cream is a dairy product which may vary in test from 18 per cent to about 50 per cent butterfat. It is produced by the separation of milk. If milk is left standing, a layer of cream at the top will be evident in a few hours. A modern centrifugal separator produces this result immediately. Cream flows from one spout of the machine, and the by-product skim milk flows from the other spout. Skim milk is an excellent feed for pigs and calves.



A Modern Cream Separator.

$$\text{Milk} = \text{Cream} + \text{Skimmilk.}$$

Most of the butterfat passes into the cream, and only a small amount is lost to the skimmilk. Variations in the per cent of butterfat in cream are caused by the manner of operation of the separator, and the different qualities of milk used.

Problems in Cream Separation.

1. How many pounds of 28% cream can be obtained from 3200 pounds of 3.5% milk, assuming no loss of milkfat in the process of separation?

SAMPLE METHOD: Find the amount of milkfat in the milk, and then compute the quantity of cream of the desired test that can be produced with this amount of milkfat.

(a) Milk:	$F = D T$	
D = 3200 lb.	$F = 3200 \times .035$	
T = 3.5% or .035	$F = 112 \text{ lb. of milkfat.}$	
(b) Cream:	$D = \frac{F}{T}$	Answer:
F = 112 lb.		
T = 28% or .28	$D = \frac{112}{.28} = \frac{400}{1}$	400 lb.
		of cream.

2. How much 33% cream can be obtained from 1650 pounds of 4.2% milk.

3. How many gallons of 24% cream can be taken from 1200 gallons of 5% milk. How much skimmilk is produced? (The quantity of skimmilk = Milk — Cream.)

4. How many pounds of milk testing 4.5% butterfat will be required to produce 180 pounds of 33% cream, assuming no loss of butterfat in the process of separation?

SAMPLE METHOD: Find the amount of milkfat needed for the cream, and then compute the amount of milk containing this quantity of milkfat.

(a) Cream:	$F = D T$
D = 180 lb.	$F = 180 \times .33$
T = 33% or .33	$F = 59.4 \text{ lb. of milkfat.}$

(b) Milk:

F = 59.4 lb.

T = 4.5% or .045

$$D = \frac{F}{T}$$

Answer:

$$D = \frac{59.4}{.045} = \frac{1\ 320.}{59.400} \quad \begin{array}{l} 1320\text{ lb.} \\ \text{of milk.} \end{array}$$

5. Find how much 3.8% milk is needed to produce 290 pounds of 19% cream.

6. How many gallons of 3.5% milk are required to make 71.75 gallons of 40% cream?

7. Find the amount of 3.6% milk needed to make 60 pounds of 30% cream? How many pounds of skim milk are produced?

The Production of Butter.

Butter is produced by churning cream testing at least 30 per cent. Usually, the buttermaker requires 35 to 40 per cent cream. The by-product in the production of butter is buttermilk. **Cream = Butter + Buttermilk.**

Although the per cent of milkfat in butter is very high, it is not 100%. Butter also contains water, casein, and salt, if desired. Thus, if 100 pounds of milkfat are present in a quantity of cream, more than 100 pounds of butter can be produced from the cream, because of the other ingredients in the butter. For example, 120 pounds of butter may result. This gain by the buttermaker of 20 pounds of butter over the original 100 pounds of milkfat is called **overrun**.

Overrun of butter is the increase in the amount of butter made from a given amount of milkfat, or it is the sum of the water, salt and casein of the butter, minus the manufacturing losses.

RULE 34. To find the per cent of overrun, divide the quantity of overrun by the quantity of milkfat, and change the fraction or decimal to per cent.

Problems in Butter Production.

1. A buttermaker produces 1035 pounds of butter from 2500 pounds of 36% cream. Compute the per cent of overrun, and the value of the overrun at 29 cents a pound.

SAMPLE METHOD

- (a) Cream: $F = D T$
 $D = 2500$ lb. $F = 2500 \times .36$
 $T = 36\%$ or .36 $F = 900$ lb. of milkfat.
- (b) Butter: Subtract
 $\text{Butter} = 1035$ lb. $\%O = \frac{0}{F}$ Answer:
 $\text{Milkfat} = 900$ lb. $\%O = \frac{135}{900} = .15$ or 15 %
 $\text{Overrun} = 135$ lb. $\%O = \frac{135}{900/135.00}$
- (c) 135 lb. overrun $\times \$0.29 = \39.15 , value of Ov.

2. If you make 420 pounds of butter from 1000 pounds of cream testing 35%, what is the per cent of overrun? What is the value of the overrun at 32 cents a pound?

3. When 1500 pounds of 35% cream are made into 630 pounds of butter, what is the per cent of overrun? Find the value of the overrun, at 27 cents a pound.

4. 391 pounds of butter are made from 850 pounds of 40% cream. Find the per cent overrun. How much buttermilk is produced? (Buttermilk = Cream - Butter.)

5. How much butter can be made from 550 pounds of 40% cream, if the per cent overrun on milkfat is 14%? How much buttermilk is produced?

SAMPLE METHOD

- (a) Cream: $F = D T$
 $D = 550$ lb. $F = 550 \times .40$
 $T = 40\%$ or .40 $F = 220$ lb. of milkfat.
- (b) Butter: Multiply
 $\text{Milkfat} = 220$ lb. $\text{Milkfat} = 220.0$ lb.
 14% Over. .14 $\text{Overrun} = 30.8$ lb.
 $\text{Overrun} = 30.8$ lb. $\text{Butter} = 250.8$ lb. Ans.
- (c) Buttermilk = $550 - 250.8$, or 299.2 lb. Answer

6. Find what quantity of butter can be produced from 950 pounds of cream testing 38% milkfat, if the per cent overrun is 20%. How many pounds of buttermilk are formed?

7. 1200 pounds of 35% cream are used to make butter. If the per cent of overrun is 17%, how much butter is produced? Find the amount of buttermilk.

GENERAL PROBLEMS IN DAIRY PRODUCTS

1. In a certain locality, the farmer is paid for milk on the following basis: \$2.20 per 100 pounds for 3.5% milk; with a 4 cent differential for each tenth of a point of butterfat under or above the 3.5 base, that is, 4 cents more per hundred pounds for each tenth of a point more than 3.5%, and 4 cents less per hundred pounds for each tenth of a point less than 3.5%. Find the amount the farmer should receive for each of the following quantities of milk:

- (a) 800 lb. of 3.9% milk (f) 850 lb. of 3.7% milk
- (b) 700 lb. of 3.2% milk (g) 950 lb. of 4.1% milk
- (c) 900 lb. of 4.6% milk (h) 750 lb. of 3.1% milk
- (d) 600 lb. of 4.3% milk (i) 650 lb. of 5.0% milk
- (e) 500 lb. of 4.9% milk (j) 875 lb. of 3.3% milk.

2. A certain cow produces 8000 pounds of milk, having an average test of 4.5%, in one year. 1400 pounds of 25% cream are separated from this milk.

- (a) Find the amount of milkfat in the milk; in the cream.
- (b) How much milkfat is lost to the skimmilk?
- (c) What is the milkfat loss at 28 cents a pound.
- (d) How much skimmilk was produced?
- (e) Find the per cent of milkfat in the skimmilk.

3. The farmer will find it valuable to compare the production of creams of different tests from the same quantity of milk. A certain cow produces an average of 6000 pounds of milk, averaging 4% test, in one year. Assume no loss of butterfat to the skimmilk. Also assume the sale of cream at a fixed price per pound of butterfat.

- (a) How much 20% cream can be produced from the milk?
- (b) How much skimmilk remains after separating the 20% cream from the milk?
- (c) How much 40% cream can be produced from the milk?
- (d) How much skimmilk does the farmer get in producing 40% cream?
- (e) How much skimmilk is wasted in producing 20% cream

instead of 40% cream? What is the value of this skimmilk, at 50 cents per 100 pounds?

Note: There may be an additional loss in the expense of shipping a greater quantity of cream.

4. Which of the following methods of disposing of milk testing 4% is the most profitable (use 1000 lb. of milk):

(a) To sell the milk at \$2.25 per 100 lb.;

(b) To produce 25% cream selling for 14 cents a pound. Value the skimmilk formed at 50 cents per 100 lb.;

(c) To make butter on the farm, overrun of 15%, and to sell the butter for 32 cents a pound and the buttermilk for 1 cent a pound. Use 40% cream. Value the skimmilk at 50 cents per 100 pounds.

5. The average yearly milk production by a Holstein-Friesian cow of advanced register, up to 1938, was 16,005 pounds, averaging 3.4% butterfat.

(a) How much butterfat per year was produced by a cow?

(b) How much butter could be made from this butterfat at an overrun of 20%?

(c) What is the value of the butter from each cow, at 31 cents per pound?

Cheese.

6. Compute the number of pounds of each component in 750 pounds of American cheddar cheese having the following composition, and check your answer by totalling the amounts:

Water, 38%; milkfat, 30%; milk solids not fat, 32%.

7. If 8.28 pounds of cheese can be made from 100 pounds of 3.0% milk, how much cheese can be made from 800 pounds of 3.0% milk?

8. How many pounds of cheese can be made from 1500 pounds of 3.5% milk, at the rate of 9.41 pounds of cheese from 100 pounds of 3.5% milk?

9. Find the amount of cheese that can be made from 1200 pounds of 4.0% milk, if 10.56 pounds of cheese can be made from 100 pounds of 4.0% milk.

10. If 12.51 pounds of cheese can be made from 100 pounds

of 4.8% milk, how much cheese can be made from 1800 pounds of 4.8% milk?

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Chapter XIV

THE STANDARDIZATION OF DAIRY PRODUCTS

THE farmer or dairyman will often find it necessary to have a dairy product of a certain butterfat content, to meet a fixed standard. This requires either raising or lowering the per cent of butterfat in a produce. For example, if cream is to be standardized to a lower butterfat test, milk or cream of lower test may be added; if the butterfat test of the cream is to be raised, a higher test cream must be added. You can compute in advance how much of each dairy product of known test to use, in order to produce the standard test required.

Finding How Many Parts of Each Product to Use.

The method of solving dairy problems in standardization has been greatly simplified through a plan devised by Prof. R. A. Pearson, of Cornell University. The Pearson rule is as follows:

Draw a rectangle and its two diagonals. At each of the two left-hand corners of the rectangle, write one of the per cents of butterfat of the dairy products to be mixed. Write the desired test per cent of the mixture at the center of the rectangle.

There are then two numbers along each diagonal of the rectangle: a per cent of one dairy product, and the desired (standard) test of the mixture. In one case the test of the dairy product is larger than the desired test, and in the other case smaller. Disregard the order, and subtract the smaller number from the larger number along each diagonal. Write each remainder at the other end of the diagonal, at one of the right-hand corners of the rectangle.

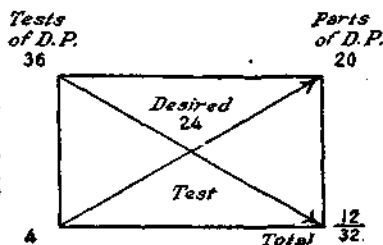
The two numbers at the right-hand corners of the rectangle

indicate the number of parts to be used of the dairy product appearing on the same *horizontal* line of the rectangle. The total of the two numbers on the right represents the total number of parts in the mixture.

Problem: How many parts each of 36% cream and 4% milk must be mixed to produce cream testing 24%?

Answer:

If 20 parts of 36% cream are mixed with 12 parts of 4% milk, the result will be a mixture of 32 parts, testing 24%.



Explanation. The tests of the original dairy products (D. P.), 36 and 4, are placed at the left of the rectangle. The desired test, 24, is placed at the intersection of the diagonals. Subtract along the diagonals and place each difference at the right, at the end of the diagonal: $36 - 24 = 12$; and $24 - 4 = 20$. Then the 20 parts correspond to the 36% cream, and the 12 parts correspond to the 4% milk.

You can use the answer in any multiple. When you mix 20 pounds of 36% cream with 12 pounds of 4% milk, you will produce 32 pounds of 24% cream; also, 100 pounds of 36% cream mixed with 60 pounds of 4% milk (multiplier is 5) will make a mixture of 160 pounds, testing 24%. Moreover, the answer or a multiple can be used in any unit; 240 quarts of 36% cream and 144 quarts of 4% milk (multiplier is 12) will produce 384 quarts of 24% cream.

Practice in Finding the Parts of Dairy Products.

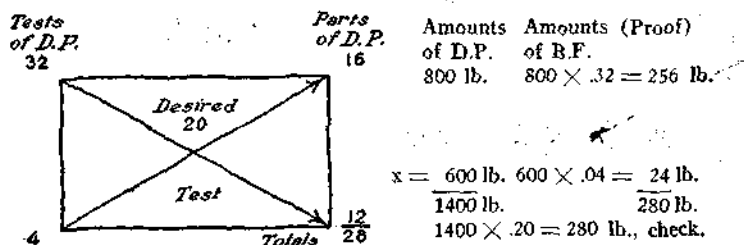
1. How many parts each of 26% cream and 5% milk must be mixed to produce cream testing 20%?
2. Mix 40% cream and 4% milk to make 35% cream.
3. A farmer has 30% cream which he desired to standardize

to 23% cream by mixing with 18% cream. Find how many parts each of 30% cream and 23% cream must be used.

4. A farmer has Guernseys averaging 4.8% milk, and Ayrshires, averaging 3.8% milk. How many cows of each breed should there be in the herd, in order that their mixed milk will test 4.1%? Assume the same amount of milk per cow.

How to Produce a Certain Amount of Standardized Product.

Problem: How many pounds each of 32% cream and 4% milk must be mixed to produce 1400 pounds of 20% cream? Prove the answer. (Note: A definite amount of mixture is required.)



$$\begin{array}{r} 1) \quad 12 \quad x \\ \hline 28 \quad 1400 \end{array}$$

$$2) \quad 28x = 16,800$$

$$\begin{array}{r} 3) \quad 28x \quad 16,800 \\ \hline 28 \quad \quad 28 \end{array}$$

$$4) \quad x = 600 \text{ lb. of 4% milk}$$

$$5) \quad 1400 \text{ lb.}$$

$$\hline - 600$$

$$800 \text{ lb. of 32% cream}$$

Answer: Use 800 lb. of 32% cream and 600 lb. of 4% milk.

Explanation. Find the parts of dairy products by the method of the rectangle, in the manner explained on pages 148 and 149. We find that we must use 16 parts of 32% cream and 12 parts of 4% milk, or a total of 28 parts. However, 16 pounds plus 12 pounds will produce only 28 pounds of mixture,

whereas the problem calls for 1400 pounds. Write the 1400 as the total of a new column, "amounts of dairy products." As we are seeking the amount of each, we will represent one of them by the letter "x." Although it is not material which we find first, it may be more convenient to take the bottom product first.

The ratio of the number of parts of 4% milk in the mixture to the total number of parts is $12/28$. The ratio of the amount of 4% milk in the mixture to the total amount is $x/1400$. These two ratios are equal, and can be written in a proportion. (Step 1). Solve the proportion for x (Steps 2 through 4) by the method on page 103. $x = 600$ lb., the amount of 4% milk. Find the amount of 32% cream required, by subtracting 600 lb. from the total quantity of mixture, 1400 lb. (Step 5). Thus 800 lb. of 32% cream are needed.

Proof. It is very advisable to prove the answer in a standardization problem, especially in view of the many steps in the solution. If we have solved the problem correctly, we should produce a mixture of 1400 pounds, testing 20% butterfat. This quantity of cream would contain 1400×0.20 , or a total of 280 pounds of butterfat.

The mixture of 1400 pounds is made up of 800 pounds of 32% cream and 600 pounds of 4% milk. The 800 pounds of 32% cream contain 800×0.32 , or 256 lb., of butterfat; the 600 pounds of 4% milk contain 600×0.04 , or 24 lb. of butterfat. $256 + 24 = 280$ lb. of butterfat.

As the total amount of butterfat in the two products used is 280 pounds, and the quantity of butterfat in the total mixture should be 280 pounds, the problem has been solved correctly.

STANDARDIZATION PROBLEMS

1. See page 105 for practice in solving proportions.
2. How many pounds each of 39% cream and 18% cream must be used to make a mixture of 840 lb., testing 36%? Prove your answer.

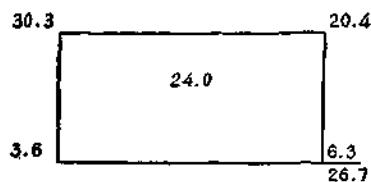
3. How many gallons each of 37% cream and 22% cream will produce a mixture of 630 gallons, testing 30%? Prove.

4. What quantities each of 19% cream and 35% cream would you mix in order to make 880 lb. of 23% cream? Prove.

5. Standardize 29% cream and 4% milk to produce 875 lb. of 18% cream. Prove.

6. How many quarts each of 3% milk and 32% cream must be mixed to make 1160 quarts of 20% cream? Prove.

7. A dairyman has 30.3% cream and 3.6% milk. How much of each must he use to make a total of 1335 pounds of 24% cream? The outline at the left shows the use of decimals in the rectangular method.



Care should be exercised in the solution of the proportion: $6.3/26.7 = x/1335$. This work can be slightly simplified, if $6.3/26.7$ is changed to $63/267$ by multiplying the numerator and denominator of the fraction by the number 10. The proportion is thus changed to: $63/267 = x/1335$.

8. Standardize 4.1% milk and 33.4% cream to make 1465 quarts of 25.0% cream. Prove your answer. (Do not round off the decimals in the proof.)

9. How many pounds of 26% cream and 3.9% milk must be mixed to produce 2210 pounds of 20% cream? Prove.

10. Mix 21% cream and 38% cream to make 500 gallons of 30% cream. Prove your answer.

Note. The answer for x will not be a whole number of gallons, in the solution of the proportion. Round off the answer to the nearest tenth of a gallon. Will the proof give an exact check of your work?

11. How many pounds each of 3% milk and 29% cream are required to produce a mixture of 800 lb., testing 18%? Prove.

12. What amounts each of 32.7% cream and 19.2% cream should you mix to make 600 quarts of 24% cream? Prove.

13. How many pounds each of 28.4% cream and 3.8%

milk should be used to produce a mixture of 700 pounds, testing 19% butterfat? Prove.

Planning the Breeds of Cows in a Herd.

14. A farmer has Jersey cows averaging 4.8% milk, and Holstein cows averaging 3.2% milk.

(a) What quantity of milk should be produced by each breed, for a total daily milk production of 480 pounds of 3.7% milk? Prove.

(b) If these Jersey cows average 25 pounds of milk a day, and the Holsteins average 33 pounds per day, how many cows of each breed should the herd contain in order to produce this quantity of milk?

15. Plan the number of cows for a herd composed of Holstein and Brown Swiss cows. The desired milk production is 1200 pounds each day, having an average test of 3.6%. Assume that the Holstein produces 50 pounds per day, averaging 3.3% butterfat, and that the Brown Swiss produces an average of 30 pounds per day of 4.1% milk. Prove your work.

16. Plan the number of cows for a herd composed of Holstein and Guernsey cows. The farmer desires a daily production of 680 pounds of 3.8% milk. Assume that the average milk production is 44 pounds, testing 3.2%, daily for Holsteins, and 30 pounds, testing 4.9%, daily for Guernseys. Prove your work.

Standardization of a Given Amount of a Dairy Product.

Problem: How many pounds of 3.2% milk must be added to 376 pounds of 27% cream in order to produce cream testing 22% butterfat? Prove your answer.

Test of D.P.	Parts of D.P.	Amounts of D.P.	Amounts of B.F.
3.2	5.0	$x = 100 \text{ lb.}$	$100 \times .032 = 3.20 \text{ lb.}$
27.0	18.8	$\frac{376 \text{ lb.}}{476 \text{ lb.}}$	$\frac{376 \times .27 = 101.52 \text{ lb.}}{104.72 \text{ lb.}}$
	Totals 23.8	$476 \times .22 = 104.72, \text{ check.}$	

$$1) \quad \frac{5.0}{18.8} = \frac{x}{376}$$

$$2) \quad \frac{50}{188} = \frac{x}{376}$$

$$3) \quad 188x = 18,800$$

$$4) \quad x = 100 \text{ lb. of } 3.2\% \text{ milk.}$$

Answer: Add 100 pounds of 3.2% milk. The total mixture will contain 476 pounds.

Explanation. In this problem, the number of pounds of one product is known, but not the total amount of mixture. The ratio of the number of parts of the products is 5.0/18.8. The ratio of the amounts of products is $x/376$. These two equal ratios are written in a proportion in Step 1. The total amount of mixture equals the sum of the two products used. Prove the example in the usual manner.

Problems in Standardizing a Given Amount of Product.

1. How many pounds of 3.5% milk must be mixed with 74 pounds of 31.5% cream to make cream testing 22% butterfat? Prove your answer.

2. A farmer adds 4.2% milk to 594 pounds of 30% cream to produce a standard 24% cream. Find the quantity of milk required. Prove the answer.

3. How much 38% cream must be added to 156 gallons of 20% cream to make a standard 25% cream? Prove the answer.

4. Standardize 185 quarts of 31.4% cream to 23% cream by adding 19.3% cream. Find the amount of 19.3% cream required and prove the answer.

Standardizing the Butterfat Test of a Herd.

5. A farmer has 11 Holstein cows each of which produces an average of 40 pounds of milk per day, testing 3.3% butterfat. He decides to add to the herd Guernsey cows, averaging 4.7% milk, in order to raise the herd test to 3.6%.

(a) How much milk per day is produced by the herd of Holstein cows?

(b) What total amount of milk must be added by the Guernsey cows to raise the butterfat test of the total herd to 3.6%?

(c) If the Guernsey cows average 30 pounds of milk each, per day, how many Guernsey cows are needed to supply the quantity of milk required in (b)?

6. A farmer has 24 Holstein cows each averaging 40 pounds of milk per day, testing 3.4% butterfat. He desires to add to the herd Jersey cows, averaging 5.0% milk, in order to raise the herd test to 3.8%.

(a) How many pounds of milk are produced by the herd of Holsteins each day?

(b) How many pounds of milk must be produced by the Jersey cows, in order to raise the butterfat test of the total herd to 3.8%?

(c) How many Jersey cows does this require, if each Jersey cow averages 20 pounds of milk per day?

(d) What will be the total amount of milk produced by the entire herd?

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Chapter XV

FEEDS

THE feeding of animals is a daily task of the farmer. The draft horse must be provided with energy in order to do its work capably; dairy cattle must be supplied with the ingredients for milk production; beef cattle and hogs must be fattened; and all the animals must be furnished with food for their sustenance.

Through learning how to feed farm animals more economically, the farmer can secure a greater profit in their maintenance. Proper feeding of farm animals is a science, and requires the knowledge of a number of important facts. What are the food requirements of the animals; what is the composition of feeds used to furnish these food substances?

Composition of Feeds.

We must know the analysis of a feed, in order to study its food value. Such an analysis considers the following constituents: (1) water, (2) protein, (3) fat, (4) fiber, (5) nitrogen-free extract, and (6) minerals. Also present in feeds in varying quantities are different classes of vitamins.

Heating will drive off the water present in a feed. The remaining substances constitute the dry matter. If the dry matter is burned, the organic matter (protein, fat, fiber, and nitrogen-free extract) will undergo changes and pass off in the form of a gas. The ash remaining is the inorganic matter or minerals. Sugar and starch are included under the heading nitrogen-free extract. Together, fiber and nitrogen-free extract are known as carbohydrates. The name carbohydrates indicates that they are composed of the elements carbon, hydrogen and oxygen. Fats (and oils) are also made up of these ele-

ments, but contain a smaller proportion of oxygen. Protein includes all nitrogeous matter, that is, substances which contain the element nitrogen in combination with other elements.

AVERAGE COMPOSITION OF SOME COMMON FEEDS

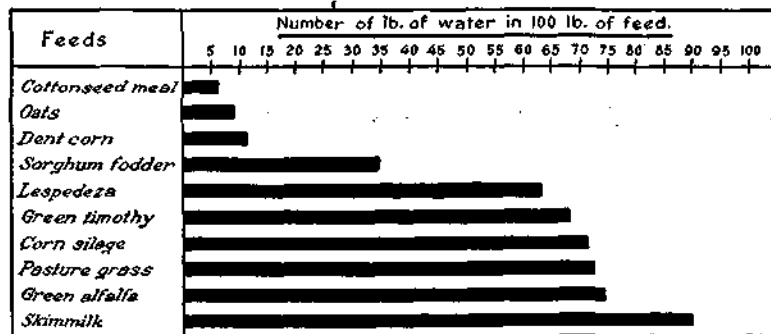
<i>Feeds</i>	<i>%</i> <i>Water</i>	<i>%</i> <i>Protein</i>	<i>%</i> <i>Fat</i>	<i>%</i> <i>Fiber</i>	<i>%</i> <i>N-free Extract</i>	<i>%</i> <i>Ash</i>
Corn Silage	71.7	2.3	0.9	6.9	16.5	1.7
Cottonseed meal..	6.5	43.2	7.2	10.6	27.0	5.5
Oats	9.3	11.0	4.9	10.7	60.5	3.6
Pasture grass	72.9	5.2	1.0	6.4	11.8	2.7
Timothy hay	11.3	6.2	2.4	30.1	45.0	5.0
Wheat bran	9.4	15.8	5.0	9.5	54.3	6.0

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Use Above Table For Problems 1 to 7.

1. Find the number of pounds of each constituent in 40 pounds of corn silage.
2. Find the number of pounds of each constituent in 1 ton of cottonseed meal.
3. What is the total percentage of carbohydrates in each of the above feeds?

FEEDS CONTAIN LARGE AMOUNTS OF WATER



4. Find the number of pounds of dry matter in (a) 6 lb., (b) 11 lb., (c) 16 lb., (d) 4 lb., of oats.
5. Find the amount of dry matter in (a) 12 lb., (b) 16 lb., (c) 20 lb., (d) 14 lb., of timothy hay.
6. Find the number of pounds of water in 500 pounds of each of the above feeds.
7. Compute the total amounts of (a) water, (b) inorganic matter, and (c) organic matter, in 250 pounds of wheat bran.

Digestible Nutrients.

A **nutrient** is a food constituent that provides nourishment to the animal. It is customary to consider only proteins, carbohydrates and fats, under the name nutrients. However, air, water, minerals and vitamins also support animal life.

Various functions are served by the different nutrients:

Proteins:—are used to repair and replace body tissues; provide for the growth of hair or wool, skin, hoofs, etc.

Carbohydrates:—are used in the production of fat, heat and energy.

Fats:—are used in the production of heat and energy.

The animal is able to digest and utilize only part of a feed which it eats. Thus the value of a feed depends upon its digestibility, as well as its composition. The digestibility of various feeds is determined by experiments with farm animals. The average per cent of a nutrient in a feed digested by an animal is called the **digestion coefficient (coefficient of digestibility)** for that nutrient in the feed. Generally, fiber has a relatively low digestion coefficient, and the digestion coefficients of nitrogen-free extracts in feeds are higher than of proteins and fats.

Finding the Digestible Nutrients in Feeds.

1. In digestion experiments with hogs in Texas, ground barley was fed, containing 12.2% protein, 2.4% fat, 7.3% fiber, and 67.2% nitrogen-free extract. The following digestion coefficients were determined: protein, 73.9%; fat, 43.3%; fiber, 21.4%; nitrogen-free extract, 84.8%. Find the number

of pounds each of the digestible nutrients in 100 pounds of the ground barley.

Method: 12.2% of 100 lb. = 12.2 lb. of protein.

(73.9% of 12.2 lb. = 9.0 lb. of digestible protein (nearest tenth of a pound). Etc.

2. A cow is feed 20 pounds of clover hay, containing 11.8% protein, 2.6% fat, 27.3% fiber, and 40.1% N-free extract. Find the amount of each digestible nutrient, if the digestion coefficients are: protein, 59%; fat, 58%; fiber, 51%; and nitrogen-free extract, 69%.

Total Digestible Nutrients.

The table, at page 291 of the appendix, lists the amounts of digestible nutrients contained in various feeds. These have been calculated from the composition of the feeds and the digestion coefficients. For each feed, the table gives the total per cent of dry matter, and the per cents of digestible protein, carbohydrates and fat. These numbers can also be used as the number of pounds of constituent in 100 pounds of feed. The feeds in the table are separated into two main classes, **concentrates** and **roughages**. Concentrates are high in digestible nutrients and low in fiber, as grains and the by-products, wheat bran, linseed meal, etc. Roughages are high in fiber content, but low in digestible nutrients, such as hay, silage, and the by-products, oat hulls, ground corn cob, rice hulls, etc.

The total of all the digestible nutrients in a feed is termed the **total digestible nutrients** (abbreviated **T. D. N.**). This total includes the digestible protein, carbohydrates (fiber + nitrogen-free extract), and fat. The energy value of fat for animals is about 2.25 or $2\frac{1}{4}$ times that of protein or carbohydrates. Therefore, the amount of digestible fat is multiplied by 2.25 ($2\frac{1}{4}$) before it is added to the quantities of digestible protein and carbohydrates. The total digestible nutrients of a feed is useful as an indicator of the approximate amount of heat or energy value of the feed. The number is an important aid in preparing feeding rations for animals. It is also employed in comparing the values of different feeds.

RULE 35. The total digestible nutrients in a feed.

- (a) The carbohydrate equivalent (C. E.) of the digestible fat equals the amount of digestible fat multiplied by 2.25 ($2\frac{1}{4}$).

FORMULA: $C. E. = 2.25 F$

- (b) The total digestible nutrients equals the sum of the digestible protein, the digestible carbohydrates, and the carbohydrate equivalent of the digestible fat.

FORMULA: $T. D. N. = P + C + 2.25 F$

Finding the T. D. N. of Feeds.

To find the total digestible nutrients of a feed when the amount of feed is not expressed, assume 100 pounds of feed as the amount. Then the answer will represent the T. D. N. per 100 pounds of feed. If the quantity of feed is specified, use the per cents to calculate the actual amounts of digestible nutrients.

Problem 1. Find the T. D. N. for dry alfalfa.

SAMPLE The following numbers are taken from the table
METHOD on page 291, as pounds of digestible nutrients in 100 pounds of dry alfalfa:

10.6 lb. of Prot.; 38.3 lb. of Carb.; 0.6 lb. of Fat.

(a) .6 lb. of Fat $\times 2.25 = 1.35$ lb. of C. E.

(b) $T. D. N. = 10.6 \text{ lb.} + 38.3 \text{ lb.} + 1.4 \text{ lb.} = 50.3 \text{ lb.}$

Problem 2. Find the T. D. N. in 50 lb. of well-matured corn silage.

SAMPLE The following per cents are from the table:

METHOD 1.3% Prot.; 15.9% Carb.; 0.7% Fat.

(a) .013 .159 .007

$\times 50$ $\times 50$ $\times 50$

.65 lb. Prot. 7.95 lb. Carb. .35 lb. of Fat.

(b) 0.35 lb. of Fat $\times 2.25 = 0.79$ lb. of C. E.

(c) $T. D. N. = 0.65 \text{ lb.} + 7.95 \text{ lb.} + 0.79 = 9.4 \text{ lb.}$

3. Find the carbohydrate equivalent of the following amounts of digestible fat contained in feeds:

(a) 4 lb. (c) 0.8 lb. (e) 60 lb. (g) 58 lb.

(b) 7 lb. (d) 0.22 lb. (f) 72 lb. (h) 31 lb.

4. Find the T. D. N. for the following feeds:

(See the table of feeds for the number of pounds each of digestible nutrients in 100 pounds of feed.)

(a) Oat straw (c) Pasture grasses

(b) Dent corn (d) Oats

5. Find the T. D. N. in the following quantities of feed:

(See table of feeds for the per cents of nutrients.)

(a) 20 lb. of dry timothy (c) 1 ton of wheat bran.

(b) 60 lb. of skimmilk (d) 1 ton of cowpea hay

6. Find the difference in the T. D. N. contained in 100 pounds of barley and 100 pounds of buckwheat (See table).

7. Which feed contains more T. D. N. for the animal: 18 lb. of soybean hay; or 16 lb. of mixed grass hay (See table)?

8. Compute the T. D. N. in a crop yield of 2.4 tons of red clover hay per acre, if there are 15.4 pounds of total digestible nutrients in 100 pounds of the hay. Calculate the T. D. N. in a crop yield of 3 tons of alfalfa hay per acre at 14.7 pounds of total digestible nutrients in 100 pounds of the hay. What is the difference between the two yields in T. D. N.?

9. Find the difference in T. D. N. between the following crops: (a) 720 pounds of oats, T. D. N. is 71.5 pounds per 100 pounds; (b) 680 pounds of rye, T. D. N. is 80.1 pounds per 100 pounds.

Use this table for Problem 10, next page.

Feeds	Protein		Fiber		N-free Extract		Fat	
	Am't.	D.C.	Am't.	D.C.	Am't.	D.C.	Am't.	D.C.
Cowpeas ...	3.0	76	3.8	60	7.0	81	0.5	59
Flax straw .	7.2	81	42.5	26	32.9	44	3.2	93
Soybean hay	14.8	75	28.4	44	37.0	61	3.3	60
Corn bran ..	9.8	58	9.8	72	61.8	82	6.4	76

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The previous table gives the per cents of constituents in the feeds mentioned, under the columns headed "am't"; these amounts can also be used as pounds per 100 pounds of feed. Under the headings "D.C." are the digestion coefficients, that is, the per cent of digestibility of the respective nutrients.

10. Find the T. D. N. for (a) cowpeas, (b) flax straw, (c) soybean hay, and (d) corn bran. Use the following steps:

- (1) Find the amounts each of digestible nutrients.
- (2) Find the carbohydrate equivalent of the digestible fat.
- (3) Find the total digestible nutrients.
- (4) Note. Carry two decimal places throughout the work, and round off the answer to one decimal place.

The Cost of Digestible Nutrients.

One of the guides in the selection of a feed is the quantity of total digestible nutrients. A feed that costs less per ton is not necessarily the cheaper feed, as it may contain a much smaller amount of total digestible nutrients. The cost of a pound of digestible nutrients is one means of making the comparison. Usually, for convenience, the cost of 100 pounds of T. D. N. is found.

1. A certain corn gluten feed containing 1552 pounds of T. D. N. in one ton sells for \$26.20 per ton. What is the cost of 100 pounds of T. D. N.?

Method: One pound costs $\frac{\$26.20}{1552}$. The cost of 100 lb.

is $100 \times \frac{\$26.20}{1552}$. Therefore, multiply 26.20 by 100 and divide the result 2620 by 1552. The answer, correct to 2 decimal places, is \$1.69 per 100 lb. of digestible nutrients.

2. Find the cost of 100 pounds of digestible nutrients in ground barley selling for \$30.20 per ton, if one ton of the feed contains 1574 pounds of T. D. N.

3. A ton of dried citrus pulp sells for \$27.50 per ton. If

there are 1520 pounds of T. D. N. in one ton, find the cost of 100 pounds of T. D. N.

4. At \$29.40 per ton for dried beet pulp, containing 1436 pounds of T. D. N. in a ton of feed, what is the cost of 100 pounds of T. D. N.?

5. If soybean oil meal sells for \$31.60 per ton, find the cost of 100 pounds of digestible nutrients in the feed.

Method: Use the table of feeds to find the T. D. N. in one ton of the feed. Then proceed as in Problem 1 on page 162. The cost of 1 pound = $\$31.60 \div \text{T. D. N.}$; and the cost of 100 pounds = $100 \times \frac{31.60}{\text{T. D. N.}}$, or $\frac{3160}{\text{T. D. N.}}$.

6. If a farmer pays \$27.00 for a ton of standard wheat middlings, what is the cost of 100 lb. of T. D. N.?

7. When red clover hay sells for \$12.80 per ton, what is the value of 100 pounds of T. D. N. in this feed?

8. If the price of oats is 48 cents per bushel, what is the cost of 100 pounds of T. D. N.? (1 bushel = 32 lb.)

The Cost of Digestible Protein in Feeds.

Farm animals must be fed certain minimum amounts of protein to repair and replace the daily wear of tissues. This protein requirement for the maintenance of farm animals must be met by the use of feeds of suitable protein content.

In many localities, feeds that are rich in digestible proteins are more expensive than feeds which are rich in digestible carbohydrates but low in protein. Thus, one pound of digestible protein generally has a greater value than one pound of digestible carbohydrates.

The method of comparing feed costs on the basis of T. D. N. does not take into consideration the higher value of protein. If you compute the cost of T. D. N. and the cost per pound of digestible protein, you will be able to judge more accurately which feeds are more economical.

1. If cottonseed meal, 43% grade, sells for \$36.30 per ton, what is the cost of a pound of digestible protein?

Method: This grade of cottonseed meal contains 35.0% digestible protein (table of feeds). One ton contains 35% of 2000, or 700 lb. of digestible protein. The cost of one pound equals $\$36.30 \div 700$, or \$0.052 (rounded off).

Answer: 5.2 cents per pound of digestible prot.

2. What is the cost of one pound of digestible protein in standard wheat middlings, at \$26.40 per ton?

3. If a ton of wheat bran sells for \$27.00, what is the cost of one pound of digestible protein?

4. Find the cost of one pound of digestible protein in linseed meal selling for \$37.40 per ton.

5. A farmer has the choice of using either of the following two feeds:

	% D.P.	Per Ton	T.D.N.
Soybean oil meal	33.2	\$31.60	1610
Distiller's dried grains . . .	22.5	\$33.50	1700

(a) Find the cost of 100 pounds of T. D. N. in each feed. Which has the greater cost, and by what amount?

(b) Find the cost of one pound of digestible protein in each feed. Which is the greater cost, and how much is the difference?

(c) Which feed is "cheaper," and why?

6. Compare the economy of the following farm grains:

	% D.P.	Per Ton	T.D.N.
Ground barley	9.3	\$30.20	1574
Ground corn	9.6	\$31.60	1430

(a) What is the cost of 100 pounds of T. D. N. of each feed? Which cost is greater, and how much is the difference?

(b) What is the cost of one pound of digestible protein in each feed? What is the difference between these costs for the two feeds?

(c) Which grain is "cheaper," and why?

Other Factors in the Comparison of Feeds.

Even though one may compute both the cost of digestible protein and the cost of the digestible nutrients, it may be difficult to compare two feeds. One feed may supply the

T. D. N. at lower cost, but the other feed may provide the protein more cheaply.

Furthermore, roughages or low-grade concentrates are high in fiber which is more difficult to digest, and thus a pound of T. D. N. in such feeds is worth less than a pound of T. D. N. in a high-grade concentrate.

These factors, and other considerations, are taken into account in the method of constants and graphs devised by Peterson of the Minnesota experiment station.

Whichever method of evaluating feeds is used, the suitability of feeds for certain animals is also of importance. The cheaper feed may not be the proper feed for the livestock in question, and hence should not be used. What should be fed the animal will be studied in the next chapter.

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Chapter XVI

THE FEEDING OF FARM ANIMALS

SCIENTISTS have performed many experiments for the purpose of determining the feeding requirements of the various farm animals. They have studied the usefulness of different feeds for supplying proper nourishment to the animals. The farmer should utilize the most recent information, in preparing a **balanced ration**. A balanced ration is an amount of feed given to the animal during a day, which supplies the proper quantities and proportion of nutrients for the nourishment of the animal.

Nutritive Ratio.

Protein has specific uses in the body of the animal, not furnished by the other nutrients. In studying feeding rations, we must distinguish between the amount of digestible protein and the amount of digestible non-nitrogenous nutrients (carbohydrates and the carbohydrate equivalent of fat). The relation between these two amounts is expressed as a ratio, termed the **nutritive ratio**.

The **nutritive ratio** (N.R.) is the ratio between the digestible protein and the digestible non-nitrogenous nutrients in a feed. Thus, if for every pound of digestible protein in turnip tops there are 4 pounds of digestible non-nitrogenous nutrients, the nutritive ratio of turnip tops is 1 to 4, written 1:4.

RULE 36. The nutritive ratio of a feed.

- (a) The total carbohydrate value of a feed equals the amount of digestible carbohydrates, plus the digestible fat multiplied by 2.25.

FORMULA: $T.C. = C + 2.25F$

- (b) The first term of the nutritive ratio of a feed is the number 1; the second term is the total carbohydrate value of the feed divided by the amount of digestible protein.

FORMULA: $N.R. = 1 : T.C./P$

Practice in Finding the Nutritive Ratio of Feeds.

1. Find the nutritive ratio of soybean oil meal.

SAMPLE METHOD The number of pounds of digestible nutrients in 100 pounds of feed is found in the table of feeds, at page 291.

- (a)
$$\begin{array}{r} 4.9 \text{ lb. Fat} \\ \times 2.25 \\ \hline 11.025 \text{ lb. C.E.} \end{array}$$
 (b)
$$\begin{array}{r} 33.5 \text{ lb. Carb.} \\ + 11.03 \\ \hline 44.53 \text{ lb. T.C.} \end{array}$$
 (c)
$$\begin{array}{r} 37.7 \text{ lb. Prot.} \\ \hline 44.53 \\ 37.7 \\ \hline = 1.2 \end{array}$$
- (d) Answer: The nutritive ratio of soybean oil meal is 1 : 1.2

2. Find the nutritive ratio of each of the following: (Assume 100 pounds as the quantity of each feed.)

- | | |
|---------------------|-----------------------|
| (a) red clover hay | (f) timothy hay |
| (b) oat straw | (g) skim milk |
| (c) wheat middlings | (h) sunflower silage |
| (d) wheat bran | (i) sweet corn silage |
| (e) cowpea hay | (j) cabbage |

Nutritive ratios are **narrow**, **medium**, and **wide**. Soybean oil meal has a **narrow nutritive ratio** because it has a large quantity of digestible protein in relation to the amount of digestible non-nitrogenous nutrients. This is indicated by the small second term of the ratio, namely 1.2. Red clover hay has a **medium nutritive ratio**, 1: 6.4. Oat straw has the **wide nutritive ratio**, 1: 48.0. The amount of digestible protein in oat straw is very small in relation to the other nutrients.

Tables of feeds found in bulletins and books often give the per cent of digestible protein and the per cent of total digestible nutrients. Taking 100 pounds of feed, if the digestible protein is subtracted from the T. D. N., the remainder is the total carbohydrate value.

3. Find the nutritive ratio of hominy feed, containing 7.8% digestible protein and 85.2% T. D. N.

Method: The total carbohydrate value = $85.2 - 7.8$, or 77.4 lb. in 100 pounds of feed. $77.4 \div 7.8 = 9.9$ (nearest tenth). Answer: N.R. is 1: 9.9

4. What is the nutritive ratio of common millet hay, having 5.2% digestible protein and 51.5% T. D. N.?

5. Find the nutritive ratios of the following feeds, and state whether each ratio is narrow, medium or wide:

- (a) Cod-liver oil meal:—49.4% dig. prot. 113.5% T. D. N.*
- (b) Vetch silage:—2.0% dig. prot., 18.8% T. D. N.*
- (c) Rice straw:—0.9% dig. prot., 39.4% T. D. N.*
- (d) Rye fodder:—2.3% dig. prot., 16.2% T. D. N.*
- (e) Buttermilk:—3.3% dig. prot., 9.1% T. D. N.*

Finding the Nutritive Ratios of Feeding Rations.

You have seen that different feeds do not have the same nutritive ratio. Some feeds have a high proportion of digestible protein, while other feeds have a low proportion of this nutrient. The requirements of different animals vary. It is therefore necessary to mix feeds in order to provide the proper amounts of the several nutrients. This is called balancing the ration. You may even have to change the ration for the same animal when the animal is put to a different use. If you calculate the nutritive ratio of a certain feed mixture, you will have one check on its suitability as a balanced ration.

Problem I. The following ration was fed to pigs in an experiment at the Oregon Agricultural Station:

(At the right of the feeds in the ration appear the per cents of digestible protein and of T. D. N. assumed to be present in the feeds.)

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	<i>Lb.</i>	<i>% Dig. Prot.</i>	<i>% T. D. N.</i>
Ground Oats	29	7.0	72.2
Ground barley	59	6.9	78.8
Linseed oil meal	4	30.6	78.2
Tankage	3	35.8	72.3
Alfalfa meal	5	10.8	53.9

Find the nutritive ratio of the mixture.

Method of Solution.

(a) Ground oats:—D.P. = $29 \times .07$; T. D. N. = $29 \times .722$

(b) Ground barley:—D.P. = $59 \times .069$; T. D. N. = $59 \times .788$

(c) Linseed oil meal:—D.P. = $4 \times .306$; T. D. N. = $4 \times .782$

(d) Tankage:—D.P. = $3 \times .358$; T. D. N. = $3 \times .723$

(e) Alfalfa meal:—D.P. = $5 \times .108$; T. D. N. = $5 \times .539$

Round off each result to two decimal places.

Arrange the results as follows:

<i>Feeds</i>	<i>Lb. of Dig. Prot.</i>	<i>Lb. of T.D.N.</i>	
Ground oats ...	2.03	20.94	(a) The total carbohydrate value:
Ground barley .	4.07	46.49	75.43 lb.
Linseed oil meal	1.22	3.13	— 8.93 lb.
Tankage	1.07	2.17	66.50 lb.
Alfalfa meal ...	0.54	2.70	(b) The nutritive ratio:
			$\frac{66.50}{8.93} = 7.4$
Totals	8.93	75.43	Answer: 1 : 7.4

Practice in Computing the Nutritive Ratio of Feed Rations.

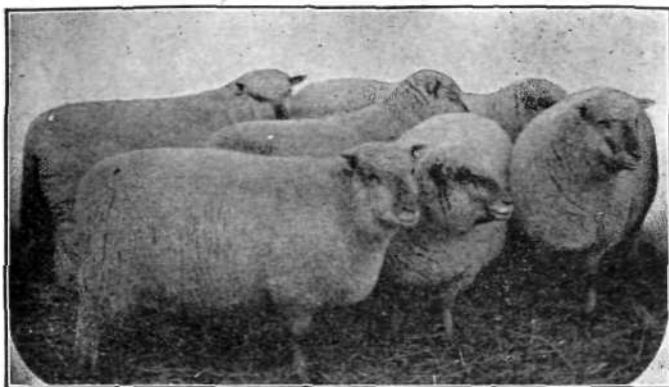
1. In an experiment at the Florida Agricultural Station, the following ration was fed daily to heifers (per thousand pounds liveweight):

	<i>Lb.</i>	<i>% Dig. Prot.</i>	<i>% T. D. N.</i>
Sugarcane silage	30	0.6	14.6
Cottonseed meal	5	37.8	80.8
Dried grapefruit refuse	15	2.14	69.55

Find the nutritive ratio of this feed mixture.

2. Calculate the nutritive ratio of the following ration recommended for wintering dry cows:

	<i>Lb.</i>	<i>% Dig. Prot.</i>	<i>% T. D. N.</i>
Grass hay	20	3.5	51.7
Cottonseed meal	1	33.9	73.2
Ground velvet beans ..	2.5	17.3	76.7



Pen of Southdown Lambs.

3. The following daily ration is recommended for fattening beef cattle in Alabama. Find the nutritive ratio.

Use the table of feeds for the per cents of nutrients, and arrange the results as follows:

<i>Feeds</i>	<i>Lb.</i>	<i>Lb. of D.P.</i>	<i>Lb. of D. Carb.</i>	<i>Lb. of D. Fat</i>
Grass hay	7			
Dent corn silage	25			
Cottonseed meal, 43% ..	6			
Totals				

Method: (a) Calculate the number of pounds of each nutrient in each feed.

(b) Find the total amount of each nutrient in the entire feeding ration.

- (c) Compute the carbohydrate equivalent of the total digestible fat in the ration; find the total carbohydrate value of the ration.
- (d) Find the nutritive ratio, using the total digestible protein, and the total carbohydrate value of the ration.

4. Tennessee experiments in feeding two-year old steers compared the following two rations:

- (a) 44.5 lb. of corn silage
4.86 lb. of peanut oil meal
- (b) 44.7 lb. of corn silage
4.86 lb. of soybean oil meal

Find the nutritive ratio of each ration. (Use the table of feeds for the per cents of nutrients.)

5. Find the nutritive ratio of the following ration for lambs that gave very satisfactory results at the Indiana Agricultural Experiment Station: (See table of feeds.)

- 1.4 lb. of corn silage
- 1.4 lb. of clover hay (Red clover hay)
- .16 lb. of shelled corn
- 1.10 lb. of cottonseed meal (43% grade).

Preparing Feeding Rations.

Here are some considerations in the preparation of feeding rations for farm animals:

1. **Nutritive ratio:**—The ration for the younger animal should have a narrow nutritive ratio, because the growing animal requires large quantities of protein. Idle animals, such as horses, have less need for protein for the repair of tissue. Thus the ration for a horse at rest should have a broader nutritive ratio than the ration for a horse at hard work. Wintering animals may require a broader nutritive ratio.

2. **Amounts of nutrients:**—The ration must contain sufficient digestible protein and total digestible nutrients. The amounts needed increase with the size of the animal. Also, the quantity required depends upon the work of the animal:

more nutrients are necessary for the horse performing hard work, and for the cow giving richer milk.

3. **Other considerations:**—The total dry matter (bulk) in the ration should not exceed the capacity of the animal. A roughage is more difficult to digest than a concentrate. Hence feed a suitable proportion of the two kinds of feeds. Minerals, vitamins, and water, require attention.

4. **Feeding standards:**—Feeding authorities have calculated the requirements of various animals in different stages of growth, and having different weights. These feeding standards are valuable guides in preparing balanced rations.



Chester White Sow.



Victoria Boar.

1. In one set of experiments in fattening lambs at the Minnesota Experiment Station, the following ration procured the greatest daily gain of weight for lambs weighing about 70 pounds:

	<i>Lb.</i>	<i>% Dry Matter</i>	<i>% Dig. Protein</i>	<i>% T. D. N.</i>
Shelled corn	1.62	78.5	6.6	74.2
Alfalfa hay	1.35	90.4	9.6	49.8
Linseed meal	0.20	91.2	27.9	77.9

- (a) Assume the above per cents of constituents, and calculate the amount of dry matter, digestible protein, and T. D. N. in each feed, and the totals for the ration (round off each result to two decimal places).
- (b) Determine the nutritive ratio of the ration.

- (c) Compare the ration with the requirements of the Morrison standard,* namely, 2.2 — 2.7 lb. of dry matter, 0.21 — 0.24 lb. of digestible protein, 1.7 — 2.0 lb. of T. D. N., and 1:6.9 — 7.4 nutritive ratio, per head daily.**

2. The Morrison feeding standard * for fattening 2-year old beef cattle, weighing 1000 pounds, is as follows: 20.0-23.5 lb. of dry matter, 1.78-1.98 lb. of digestible protein, 16.0-18.8 lb. of T. D. N., 1:7.5-8.5 nutritive ratio, per head daily. Two rations are suggested below:

<i>Ration A.</i>	<i>Ration B.</i>
Corn silage .....25 lb.	Cottonseed hulls 9 lb.
Red clover hay 4 lb.	Cowpea hay 2 lb.
Corn .....14 lb.	Corn .....10 lb.
Linseed meal .....1.25 lb.	Cottonseed meal (41%) 1 lb.

Select the ration that satisfies the feeding standard more closely, in the following manner:

- Using the table of feeds on page 291, compute the amount of dry matter, and the amount of each nutrient in each feed, and the totals for each ration (round off to 2 decimal places throughout the problem). Arrange the results in tabular form.
- Calculate the amount of T. D. N. in each ration.
- Find the nutritive ratio of each ration.
- State which of these two rations is better, according to the feeding standard.**

FEEDING DAIRY CATTLE †

The dairy cow should receive sufficient amounts of the following: (1) total digestible nutrients; (2) protein of a suit-

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** A ration can satisfy a feeding standard approximately.

† The remainder of this chapter is optional.

able quality; (3) fat; (4) minerals, especially ordinary salt, calcium and phosphorus; (5) vitamins A and D; and (6) fresh water.

Roughages and concentrates fed in proper quantities, supply the required nutrients. Cattle can consume large amounts of roughage, because of the great capacity of their stomachs. Concentrates, in the form of grain mixtures, are used to complete the nutrient requirements of the cow. More or less roughage may be included in the daily ration, according to the availability and the cost of the roughage.

Growth and other body processes of the cow depend upon protein. Also, milk is rich in protein. It is thus important to give careful consideration to the amount of protein in the preparation of the rations of dairy cattle. Part of the protein is supplied by the roughage fed. The balance must be furnished by the grain mixture. The following table indicates what per cent of protein a grain mixture should contain if fed in combination with an average amount of certain roughages.*

Grain mixture should contain:

<i>Kind of Roughage</i>	<i>% Dig. Prot.</i>
Non-legume hay and corn silage	17.4
Mixed hay (30% legumes) and corn silage	14.2
Clover hay and corn silage	11.1
Alfalfa or soybean hay and corn silage	9.5

Making a one ton grain mixture. Concentrates vary in protein content. They may be classified as follows:

Low protein:—barley, oats, corn, etc.

Medium protein:—wheat bran, wheat middlings, etc.

High protein:—corn gluten feed, field beans, etc.

Very high protein:—cottonseed meal, linseed meal, etc.

The table at page 292 states the per cents of different feeds to use in order to provide the necessary protein.

* Cornell Extension Bulletin, Number 363.

Computing the Per Cent of Protein in Concentrate Mixtures.

1. When non-legume hay and corn silage are the roughage, a proper amount of protein can be supplied by a grain mixture, of which low protein feeds are 40%, medium are 15%, high are 25%, and very high are 20%. Check the per cent of total digestible protein in the following mixture:

400 lb. of ground oats	}	40% low protein feeds
400 lb. of ground barley		
300 lb. of wheat bran	}	15% medium protein feeds
300 lb. of distillers' corn dried grains		
200 lb. of corn gluten feed	}	25% high protein feeds
200 lb. of cottonseed meal, 43% protein		
200 lb. of soybean oil meal	}	20% very high protein

Method: Calculate the amount of protein in each quantity of feed (See table of feeds). Then compute the total digestible protein; this is the amount of protein in one ton of feed mixture. The per cent of digestible protein is obtained by dividing the total digestible protein by 2000 lb. (1 ton).

2. With mixed hay and corn silage as roughage, use 50% low protein feeds, 15% medium, 25% high, and 10% very high. Check the per cent of digestible protein in this mixture:

500 lb. of ground barley	}	50% low protein feeds
500 lb. of ground oats		
300 lb. of wheat bran	}	15% medium protein feeds
300 lb. of distillers' corn dried grains		
200 lb. of corn gluten feed	}	25% high protein feeds
200 lb. of soybean oil meal		
		10% very high protein

3. Check the per cent of total digestible protein in the following grain mixtures. What per cents of the different classes of concentrates are used?

- | | |
|------------------------------|-------------------------|
| (a) 600 lb. of ground barley | (b) 700 lb. ground corn |
| 600 lb. of ground corn | 700 lb. ground oats |
| 300 lb. of wheat bran | 300 lb. wheat bran |
| 300 lb. of dist. corn gr. | 200 lb. wheat middlings |
| 200 lb. linseed meal | 100 lb. dist. corn gr. |

Note: Feed 20 lb. of salt to the ton with these mixtures; also 20 lb. of ground limestone with non-legume hay.

Quantity of Feed for the Individual Cow.

The amount of feed for the individual cow depends upon the quantity of milk the cow produces, and the butterfat content of the milk. Various scientific investigations have studied the daily feeding of dairy cows, according to the milk production of the cow, and the butterfat test of the milk. The United States Department of Agriculture suggests the following feeding practice, derived mostly from experiments at Beltsville, Maryland: *

Feed daily:

- 1) 3 lb. of silage for each 100 lb. of live weight.
- 2) All the good hay the cow will eat twice daily. This will amount to about $1\frac{1}{4}$ lb. per 100 lb. live weight.
- 3) Grain in the following quantities:—

To Jersey cows yielding 10 lb. of milk or less, give no grain; but for every pound over 10, give 0.6 lb. of grain. (0.5 lb. to 0.6 lb. are permitted.)

To Holstein cows yielding 16 lb. of milk or less, give no grain; but for every pound over 16, give 0.4 lb. of grain.

To Guernsey cows yielding 12 lb. of milk or less, give no grain; but for every pound over 12, give 0.5 lb. of grain.

To Ayrshires yielding 14 lb. of milk or less, give no grain; but for every pound over 14, give 0.45 lb. of grain.

* United States Dept. of Agr., Farmers' Bull. No. 1626.

Practice in Feeding Dairy Cows.

1. Calculate the amount of feed for a Holstein cow which weighs 1000 lb., and gives 28 lb. of milk daily.

Method: (a) $10 \times 3 = 30$ lb. of silage.

(b) $10 \times 1\frac{1}{4} = 12.5$ lb. of hay.

(c) $28 - 16 = 12$ lb. of milk over 16 lb.

$12 \times 0.4 = 4.8$ lb. of grain.

Compute the daily feed for the following dairy cows:

2. Jersey cow:—900 lb., giving 21 lb. of milk.

3. Guernsey cow:—1300 lb., giving 22 lb. of milk.

4. Ayrshire cow:—1200 lb., giving 25 lb. of milk.

5. Holstein cow:—1100 lb., giving 31 lb. of milk.

6. Jersey cow:—800 lb., giving 19 lb. of milk.

7. Guernsey cow:—1400 lb., giving 26 lb. of milk.

FEEDING HORSES—Net Energy Value of Feeds.

Feeding rations for animals can be prepared according to the **net energy value** of feeds. From the value of the feed as a source of energy to the animal are deducted the losses in the excrement of the animal and the energy consumed in the process of digestion, etc. The balance is the **net energy value** of the feed. Calculation by net energy values of feeds has an advantage over the use of total digestible nutrients, in taking into consideration the loss of feed value in the utilization of the nutrients by the animal. The table at page 293 expresses the amount of digestible protein and the net energy value of different feeds. The data is sufficiently accurate for use in preparing rations for horses.

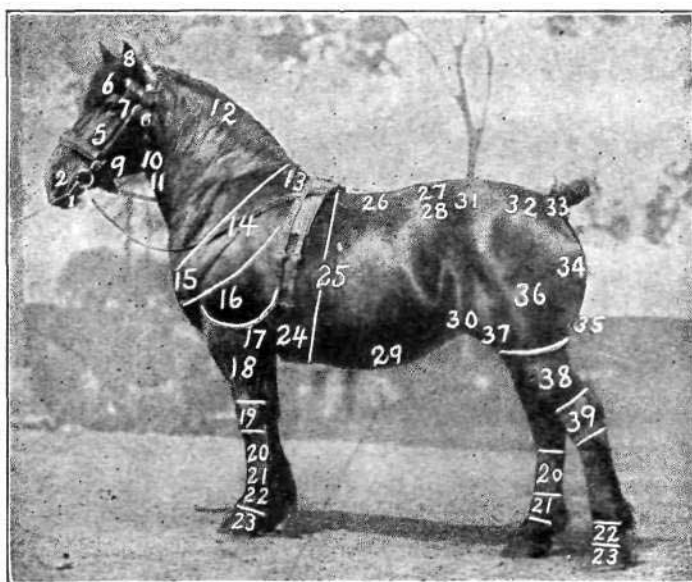
The following feeding standards for 1000-pound work horses are recommended by the United States Department of Agriculture: *

* U. S. Department of Agriculture, Farmers' Bull. No. 1030.

<i>Kind of work</i>	<i>Digestible protein Pounds</i>	<i>Net energy value Therms</i>
For light work.....	1.0	9.8
For medium work.....	1.4	12.4
For heavy work.....	2.0	16.0

Dry matter: From 16 to 25 pounds daily for the 1000-pound horse, according to the amount of work performed.

Computing the ration. For a horse or mule at medium work, it is convenient to estimate 1.1 pounds of grain per 100 pounds of live weight, and 1.2 pounds of roughage per 100



The Points of The Draft Horse: 1, chin; 2, nostril; 4, nose; 5, face; 6, forehead; 7, eye; 8, ear; 9, lower jaw; 10, throat-latch; 11, wind-pipe; 12, crest; 13, withers; 14, shoulder; 15, joint shoulder; 16, arm; 17, elbow; 18, forearm; 19, knee; 20, cannon; 21, fetlock joint; 22, pastern; 23, hoof; 24, foreflank; 25, hearth girth; 26, back; 27, loin; 28, coupling; 29, belly; 30, hindflank; 31, hip; 32, croup; 33, tail; 34, buttocks; 35, quarters; 38, gaskin; 39, hock.

pounds. Thus the daily amount for a 1000-pound horse is about 11 pounds of grain and 12 pounds of hay. Select the feeds and then check with the standard: 1.4 lb. of digestible protein, and 12.4 therms of energy. It may be necessary to change the amounts and kinds of feed selected if the standard requirements are not provided. However, a slight excess is permissible. Below is a suitable ration.*

1000-LB. HORSE AT MEDIUM WORK

<i>Ration</i>	<i>Pounds Dig. Prot.</i>	<i>Therms Energy</i>
11 lb. shelled corn	0.770	9.4050
6 lb. cowpea hay	.552	2.2554
6 lb. corn stover	.096	1.8972
Totals	1.418	13.5576

Compute the last two columns from table at pages 293, 294, which gives the lb. of protein and therms of energy per 100 pounds of feed.

Check the following feeding rations for 1000-pound horses, for the standard requirements in protein and energy:

- | | |
|------------------------|-------------------------|
| 1. Horse at light work | 2. Horse at medium work |
| 8 lb. barley (rolled) | 12 lb. oats |
| 4 lb. alfalfa | 1 lb. cowpeas (cracked) |
| 5 lb. prairie hay | 11 lb. timothy hay |

3. Calculate the number of pounds of digestible protein and therms of energy in the following ration for a 1000-lb. horse at hard work. Does this ration meet the standard requirements?

5 pounds of cowpea hay
9 pounds of corn stover
13 pounds of corn (shelled)
1½ pounds of cottonseed meal

* U. S. Department of Agriculture, Farmers' Bull. No. 1030.

4. The standard daily requirement for a 1000-pound idle horse is 0.6 pounds of digestible protein and 7.3 therms of energy. Which of the following two rations should be used?

- | | |
|----------------------------|----------------------|
| (a) 3.5 lb. corn (shelled) | (b) 3 lb. oats |
| 3 lb. cowpea hay | 3 lb. red clover hay |
| 10 lb. oat straw | 10 lb. oat straw |

Note: Salt should also be given to the horse; an average of $\frac{3}{4}$ of an ounce daily is sufficient in ordinary cases.

COMMERCIAL MIXED FEEDS.

Numerous commercial mixed feeds are on the market. Should the farmer mix his own feeds or purchase the commercial mixed feed? The answer depends upon the cost of the ingredients in the home mixture and the labor, in comparison with the price of the commercial mix supplying the same food values.

It is often difficult for the farmer to determine the exact composition of the commercial mix. In the case of closed formula feeds, usually not very much information is stated concerning the ingredients, depending upon the requirements of the state laws. Suppose only the total per cents of protein, fat and fiber are stated on the tag. In judging such feeds, you may consider less than 4% fat and more than 10% fiber unsatisfactory, as otherwise the amount of T. D. N. will probably be too low.*

Open-formula feeds, usually sold by co-operative organizations, bear declarations of per cents of nutrients, the T. D. N., and the ingredients. Open-formula mixed feeds can be compared in cost to the home mixture by computing the cost of the T. D. N. and digestible protein in the mixtures.

* Cornell Extension Bulletin No. 363.

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Chapter XVII

SOIL FERTILITY

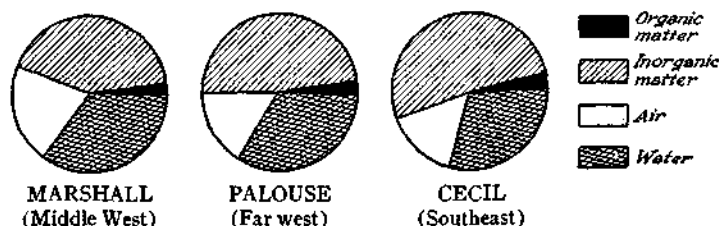
SOIL is the very foundation of agriculture. By proper soil management, the farmer can maintain the soil fertility and productivity. Some of the most important practices are: (1) suitable tillage; (2) providing an adequate supply of the elements required for plant growth; (3) maintaining the supply of organic matter; (4) rectifying soil acidity; (5) sufficient water supply and drainage; and (6) control of erosion by rotation, cover cropping or other means.

What is soil?

Soils contain solid, liquid and gaseous material. These constituents must exist in proper proportions in order that the soil may be a suitable medium for the growth of plants.

The solid portion of soil generally consists of inorganic and organic matter. The inorganic part is formed by the breaking up of rock; the organic part is made up of living and dead plants and animals and their products.

The liquid portion of soil consists of water in which are quantities of dissolved mineral matter, carbon dioxide and oxygen. Air occupies the pore space of the soil that is not already filled with water.



The proportion of various constituents in certain soils of the United States. (Composition by volume). U. S. Yearbook of Agriculture, 1938, page 892.

Classification of Soils.

One method of classifying soils is according to texture. The texture of a soil is determined by the proportion of sand, silt and clay particles it contains. Clay particles are the smallest, silt particles are next in size, and sand is the largest of the three. The main classes of soils in order of increasing amount of silt and clay are as follows: sand, loamy sand, sandy loam, silt loam, clay loam, and clay. Moisture and air content of soils, and the ease of tillage, depend upon texture. Sands lose moisture readily; clay soils lack aeration; sands are easiest to till.

Elements Required for Plant Growth.

Plants must have "food" for their growth. Carbon, hydrogen, oxygen, nitrogen, phosphorous, potassium, calcium, magnesium, iron and sulphur, have long been recognized as important for plant growth. The growth of a plant will be limited in some way by an insufficient supply of one of these elements. Modern scientists have discovered the need for other elements, including manganese, boron, copper and zinc.

Carbon, hydrogen, and oxygen, are taken by the plants from the air and water. The remaining (mineral) elements are found in the soil, produced by the wearing down of rocks. Although these minerals may be present in the soil in large quantities, only limited amounts are in an "available" state, that is, usable by plants.

Some nitrogen is obtained from the air by legumes. These are plants that procure this element through root nodules.

Problems in Soil Composition.

1. Find the number of pounds of moisture in 2,000,000 pounds (standard weight of one acre of soil, plow depth) of each of the following samples of soil:

- (a) A fine sandy soil, containing 11.7% moisture;
- (b) A silt loam soil, containing 17% moisture;
- (c) A silty clay loam soil, containing 20.4% moisture;
- (d) A clay soil, containing 27% moisture.

2. How much organic matter is there in 2,000,000 lb. of each of the following soils:

- (a) A fine sandy loam soil-1.89% organic matter,
- (b) A silt loam-2.41% organic matter?



A Freshly Plowed Heavy Red Clay Soil.

Courtesy of Michigan Agricultural Experiment Station.

Elements in soils. Various soil tests reveal great variations in the weights of different classes of soils. The per cents of elements in soils also vary widely. For the purpose of giving a general idea of the amounts of the more important elements in soils, the following weights will be assumed for one acre of topsoil (about $6\frac{2}{3}$ in. deep):

Sandy loam soil	2,600,000 lb.
Silt loam soil	2,150,000 lb.
Clay soil	1,540,000 lb.

3. Find the number of pounds of nitrogen in one acre of topsoil, for the following soils:

- (a) Sandy loam soil, containing 0.11% nitrogen;

- (b) Silt loam soil, containing 0.18% nitrogen;
 - (c) Clay soil, containing 0.36% nitrogen.
4. How many pounds of phosphorus are there in one acre of topsoil of each of the following soils:
- (a) Sandy loam soil, containing 0.04% phosphorus;
 - (b) Silt loam soil, containing 0.10% phosphorus;
 - (c) Clay soil, containing 0.05% phosphorus?
5. Find the amount of potassium in one acre of topsoil of each of the following soils:
- (a) Sandy loam soil, containing 0.61% potassium;
 - (b) Silt loam soil, containing 1.69% potassium;
 - (c) Clay soil, containing 2.92% potassium.

SOIL LOSSES.

Leaching:—This is the loss of soil constituents which are carried off in solution in water. Cover crops can be used as a control of leaching. Plant nutrients that would otherwise be lost by leaching are retained in the cover crops.

Erosion:—This is the loss of the soil itself because of wind, the run-off of water, and other causes. Of course, plant nutrients are carried off with the soil. The subsoil contains smaller amounts of nitrogen and phosphorus; hence erosion causes a serious loss in these elements. Controls for erosion are: cover cropping, terracing, contouring, and many other means.

A Study of Soil Losses by Leaching and Erosion.

1. Investigations by Cornell of annual losses of certain nutrient elements in drainage waters by a silty clay loam soil showed the following yearly losses per acre: *

<i>Soil use:</i>	<i>Nitrogen</i>	<i>Phosphorus</i>	<i>Calcium</i>
Bare	69.0 lb.	86.8 lb.	557.2 lb.
Rotation	7.8	69.1	322.0
Grass	2.5	74.5	364.0

Note: Only a slight amount of potassium was lost.

* 1938 Yearbook, U. S. Dept. of Agr., page 87.

(a) How many pounds loss of each element was prevented by using the rotation instead of leaving the ground bare, on 35 acres of land?

(b) How many pounds loss of each element was avoided by the use of grass instead of leaving the ground bare, on 42 acres of land?

(c) Which is the best practice to prevent loss of nitrogen by leaching? How much less nitrogen is lost on 72 acres of land, when grass is grown instead of using the rotation?

(d) Which is the best practice to avoid loss in phosphorus by leaching? Compare the losses in phosphorus on 62 acres of land, 1) when using rotation, 2) when growing grass.

(e) How much loss in calcium is prevented on 34 acres of land, by using the rotation instead of grass?

2. In an experiment at the Ohio Agricultural Station, it was found that when there was a soil loss of 11.1 inches the average corn crop dropped from 44.4 bushels per acre to 28.9 bushels per acre (complete fertilizer was used continuously). What is the value of such a crop loss due to erosion on 45 acres, at 52 cents per bushel of corn?

3. In the Ohio experiments, the average oat crop dropped from 48.8 bushels per acre to 38.8 bushels per acre when there was a soil loss of 5.5 inches. What is the value of the crop loss on 65 acres, at 23 cents per bushel.

4. Experiments at Tyler, Texas, showed that it is difficult to restore the fertility of eroded soil, even with the use of large amounts of fertilizer. The average yield per acre of seed cotton on a fine sandy loam soil was 360 lb. on unfertilized land, and 580 lb. on fertilized land. Where the topsoil had been removed, the yield was 50 lb. of seed cotton per acre on unfertilized land, and 225 lb. of seed cotton per acre on fertilized land.

(a) Under which condition is the yield the lowest?

(b) What is difference in tons of yield on 38 acres of each kind of fertilized land?

(c) What is difference in tons of yield on 52 acres of each kind of unfertilized land?

(d) What is the difference in tons of yield on 86 acres of fertilized eroded land, and on the same amount of unfertilized normal land?



Soil Conservation. What measures have been taken here for the control of soil erosion?

(Courtesy of A. F. Gustafson.)

REMOVAL OF ELEMENTS FROM THE SOIL BY CROPS.

As plants take large quantities of mineral elements from the soil, the supply of these elements in the soil is diminished. In general, the mineral elements removed by crops from soils to the greatest extent are nitrogen, phosphorus, potassium, and also calcium, and soils are more usually deficient in these elements. The study of this loss to the soil is important, because of its effect upon soil fertility.

To calculate the quantity of the elements nitrogen (N), phosphorus (P), potassium (K), and Calcium (Ca), removed by a certain crop, use the per cents contained in the table of fertilizing constituents in farm products, page 295. In the case of legumes (alfalfa, clover, peas, vetch, etc.), assume no loss in nitrogen to the soil, because the amount of nitrogen found in a crop of legumes is approximately equal to the amount taken by the legume from the air. (See page 192 for additional discussion of this fact.)

1. How many pounds each of nitrogen, phosphorus, potassium, and calcium, are removed from the soil by a crop yield of 356 bu. of wheat grain and $17\frac{1}{2}$ tons of wheat straw?

Method: (a) $356 \times 60 = 21,360$ lb. of wheat grain.

(See table page 280 for number of lb. to a bu.)

(b) $2000 \times 17\frac{1}{2} = 35,000$ lb. of wheat straw.

(c) Change to decimals the per cents of fertilizing constituents in the products, and then multiply.

(d) Find the total of each element.

The amounts of elements removed by the wheat grain are:

$$\begin{array}{r} 21,360 \text{ lb.} \\ \times .021 \\ \hline N = 448.560 \text{ lb.} \end{array}$$

$$\begin{array}{r} 21,360 \text{ lb.} \\ \times .0044 \\ \hline K = 93.984 \text{ lb.} \end{array}$$

$$\begin{array}{r} 21,360 \text{ lb.} \\ \times .0043 \\ \hline P = 91.848 \text{ lb.} \end{array}$$

$$\begin{array}{r} 21,360 \text{ lb.} \\ \times .0003 \\ \hline Ca = 6.408 \text{ lb.} \end{array}$$

The amounts of elements removed by the wheat straw are:

$$\begin{array}{r} 35,000 \text{ lb.} \\ \times .0061 \\ \hline N = 213.5 \text{ lb.} \end{array}$$

$$\begin{array}{r} 35,000 \text{ lb.} \\ \times .008 \\ \hline K = 280 \text{ lb.} \end{array}$$

$$\begin{array}{r} 35,000 \text{ lb.} \\ \times .0007 \\ \hline P = 24.5 \text{ lb.} \end{array}$$

$$\begin{array}{r} 35,000 \text{ lb.} \\ \times .0022 \\ \hline Ca = 77 \text{ lb.} \end{array}$$

The total amounts removed by the crop are:

$$\begin{array}{r} 448.56 \\ 213.50 \\ \hline N = 662.06 \text{ lb.} \end{array}$$

$$\begin{array}{r} 93.984 \\ 280.000 \\ \hline K = 373.984 \text{ lb.} \end{array}$$

$$\begin{array}{r} 91.848 \\ 24.500 \\ \hline P = 116.348 \text{ lb.} \end{array}$$

$$\begin{array}{r} 6.408 \\ 77.000 \\ \hline Ca = 83.408 \text{ lb.} \end{array}$$

Find the amount of nitrogen, phosphorus, potassium and calcium, removed from the soil by each of the following crop yields per acre:

(See page 295, table of fertilizing constituents in crops.)

- | | |
|----------------------------|-------------------------------|
| 1. 2.5 tons of timothy hay | Legumes:— |
| 2. 9.2 tons of turnips | 5. 3.8 tons of alfalfa hay |
| 3. 160 bu. of potatoes | 6. 2.6 tons of red clover hay |
| 4. 28 tons of sunflower | 7. 2.2 tons of soybean hay |

Find the total number of pounds of each element removed by the following crops (Use the table, page 295.):

8. 54 bu. of oat grain, and 1.5 tons of oat straw.
9. 26 bu. of rye grain, and 1.2 tons of rye straw.
10. 18 bu. (50 lb.) of buckwheat grain, and 2 tons of straw.
11. 55 bu. of corn grain, 1.6 tons of corn stover, and 600 lb. of cob.

The sale of any farm product, milk, fruits, beef, etc., constitutes a loss to the farm of the plant food elements contained in the products.

12. How much of each element is lost to a farm by the sale of 1500 lb. of milk, which contains 0.56% nitrogen, 0.09% phosphorus, 0.14% potassium, and 0.12% calcium?

13. Find the amounts of fertilizing constituents lost by the sale of 1500 lb. of skimmilk, containing 0.59% nitrogen, 0.12% phosphorus, 0.14% potassium, and 0.14% calcium.

14. Apples are 0.04% nitrogen, 0.01% phosphorus, 0.09% potassium, and 0.01% calcium. How many pounds of each plant food element are lost to a farm when 520 bushels of apples are sold.

15. What is lost to a farm in food elements, if 4500 lb. of wool are sold? Wool contains 5.4% nitrogen, 0.03% phosphorus, 4.6% potassium, and 0.01% calcium.

NOTE: See page 296, of the appendix, for a table of the quantities of plant food elements contained in certain standard crops. This table can conveniently be used to determine the loss of elements by soils, and the figures can be adjusted pro-

portionately for crop yields different from the standards in the table.

The Use of Manure Restores Elements Lost by Cropping.

When crops are fed to the farm animals, only part of the fertilizing constituents in the feeds is retained by the animal. The balance is excreted by the animal. Additional losses occur in the storage and use of the manure. If the manure is applied to the soil, then only a partial loss of elements removed by the crops will result. Various estimates of the per cents of these losses of elements have been made.

In the following problems, assume that when manure is properly handled, it returns to the soil the following per cents of the elements contained in the crops fed: 50% of the nitrogen, 70% of the phosphorus, and 70% of the potassium. Thus, the following losses of elements are sustained by the soil by cropping, if the crop is used as feed and the manure is applied to the soil:

Nitrogen—50%, Phosphorus—30%, and Potassium—30% loss.

Example. How much nitrogen, phosphorus, and potassium, are lost to the soil by growing and feeding 50 bu. of oats, and returning to the soil the manure produced.

METHOD. The following elements are contained in a crop of 50 bu. of oats (Table page 296):

32 lb. of N	5.7 lb. of P	8.0 lb. of K
$\times .5$	$\times .3$	$\times .3$
Losses: $\overline{16}$ lb. of N	$\overline{1.71}$ lb. of P	$\overline{2.4}$ lb. of K

Note. A very small amount is lost from straw that is used for bedding.

Determine the number of pounds of nitrogen, phosphorus, and potassium, lost to the soil, if the following crops are grown and fed, and the resulting manure is applied to the soil:

Note. For the legumes in examples 6-8, assuming a nitrogen gain to the soil of 50%.

- | | |
|-------------------------------|-----------------------------|
| 1. 20 bu. of buckwheat grain. | 5. 35 bu. of barley grain. |
| 2. 20 bu. of rye grain. | 6. 3 tons of alfalfa hay. ▲ |
| 3. 2 tons of timothy hay. | 7. 2 tons of clover hay. |
| 4. 50 bu. of corn grain. | 8. 2 tons of soybean hay. |

9. A farmer purchases and feeds to the animals 50 bushels of corn grain. If the manure produced is applied to the soil, how much does the soil gain (50% N, 70% P, and 70% K)?

10. A farmer bought 20 tons of timothy hay, which he fed to the animals. He hauled all the manure produced to the fields. How many pounds of nitrogen, phosphorus, and potassium, were added to the soil?

11. 8 tons of clover hay were purchased and fed. Find the number of pounds of nitrogen, phosphorus, and potassium gained by the soil, if the manure produced was applied to the soil.

Legumes and Crop Rotations.

Legumes are plants which take nitrogen from the air by the action of bacteria in nodules on the roots, a process called nitrogen-fixation. In addition to their ability to draw nitrogen from the air, legumes improve soil conditions by making the soil nitrogen more available.

Part of the nitrogen in a legume is removed from the soil, and part from the air (usually the greater amount). If a legume crop is harvested, it may be assumed in general that there is no nitrogen loss to the soil, but that the nitrogen in the crop equals the amount taken from the air. The quantity taken from the soil remains in the stubble. If a legume crop is turned under, then the amount of nitrogen in the crop is a gain to the soil. In green manuring, there is little or no change in the phosphorus or potassium content of the soil.

The practice of **crop rotation** consists of growing a sequence of varied crops instead of growing the same crop continually. When a legume is used in the rotation, the nitrogen status of the soil is greatly improved.

In the following problems, use the figures in the table of

elements in crops on page 296, unless the problem states the per cents of elements in a certain crop.

1. Find the amount of nitrogen added to the soil by turning under the following crops of legumes:

- (a) 4 acres of alfalfa hay, averaging 3 tons per acre.
- (b) 3.5 acres of clover hay, averaging 2 tons per acre.
- (c) 5 acres of soybean hay, averaging 3 tons per acre.
- (d) 35 tons of cowpea hay (3.56% nitrogen).
- (e) 25 tons of vetch (0.61% nitrogen).
- (f) 40 tons of lespedeza (2.14% nitrogen).

2. Corn is grown for two successive years on the same field. If the crop each year averages 50 bu. of corn grain, 3000 lb. of stover, and 500 lb. of cob, per acre, how much nitrogen is removed per acre by this crop?

3. Corn is grown the first year, and clover is grown the second year on the same field. The crop yield per acre of corn is the same as in problem 2; the crop yield of clover is 1.5 tons per acre. If the clover is green manured, is there a loss or a gain of nitrogen to the soil? What is the amount of loss or gain? (This may be called the net balance.)

4. A wheat crop of 25 bu. of grain per acre and 2500 lb. of wheat straw per acre is followed by a winter crop of 3 tons of crimson clover (2.26% nitrogen) per acre which is turned under. Find the net balance of nitrogen.

5. The following crops were grown in a three year rotation on one acre:

- 1st year—50 bu. of oat grain and 2500 lb. of straw,
- 2nd year—2 tons of clover which are green manured,
- 3rd year—100 bu. of potatoes.

- (a) What is the net balance of nitrogen to the soil?
- (b) How many pounds of phosphorus and potassium are removed from the soil?

6. A four year rotation consisted of the following crops on one acre:

- 1st year—50 bu. of corn grain, 3000 lb. of corn stover, and 500 lb. of cobs,

2nd year—15 bu. of soybean grain and 3000 lb. of straw,

3rd year—25 bu. of wheat grain and 2500 lb. of straw,

4th year—2 tons of clover which are green manured. •

(a) What is the net gain or loss of nitrogen to the soil?

(b) How many pounds of phosphorus and potassium are lost to the soil?

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Chapter XVIII

FARM MANURE AND COMMERCIAL FERTILIZER

LEACHING, erosion, and cropping, steadily diminish the amount of plant food elements in the soil. The farmer must avoid a decreased productivity of the soil by compensating for these losses. Farm manures and commercial fertilizers, in proper amounts, can be used to replace the lost elements.

FARM MANURE.

About one billion tons of manure are produced annually by the livestock on American farms. If properly handled and utilized, this manure could produce \$3,000,000,000 worth of increase in farm crops. In Michigan, for example, the value of the manure produced by all farm animals is about one and one-half times the value of all the milk produced in that state.* Perhaps as much as two-thirds of the value of this manure in the Nation is wasted.

The Quantity of Manure Produced by Farm Animals.

1. If a 1000-pound horse produces about 40 pounds of solid excrement and 9 pounds of liquid excrement daily, how many tons of manure are produced by the horse in one year?
2. How many tons of manure will be produced in one year by a 1000-pound cow, if the total daily excrement is 75 lb.?
3. When a 500-pound hog produces 25 pounds of solid excrement and 15 pounds of liquid excrement daily, find the number of tons of manure produced in one year.

* Michigan Experiment Station Extension Bull. No. 71.

4. If a 1000-pound steer produces about 40 lb. of excrement daily, how many tons are produced in one year?
5. 1000 pounds of poultry produce about 23 pounds of excrement daily. Find the number of tons produced in one year?
6. Five horses will produce one ton of manure (including the bedding) in about six days. At this rate, how much manure would be produced by 10 horses during 5 winter months.
7. 40 beef cattle can produce one ton of manure (including bedding) in one day. Find the amount of manure produced by 240 beef cattle during 6 winter months.
8. If 250-pound hogs produce 25 pounds of manure (including bedding) daily, find the total amount produced by sixteen 250-pound hogs in 160 days. How many acres will this manure cover, at 8 tons per acre?



A Modern Concrete Manure Pit Saves Valuable Plant Food Elements.

The Value of Farm Manure.

Farm manure consists of the solid and liquid excrements of farm animals, and includes soiled bedding, wasted feed, etc. Manure is of value to the farmer because of its usefulness to

the soil. The benefits derived by the soil from the use of manure are threefold:

I. The humus in the manure improves the physical character of the soil, and the water and air capacity of the soil.

II. The organic content of manure promotes the activity of bacteria in the soil which change plant nutrients in the soil into an "available" form for plant use. Certain organic constituents of manure increase plant growth.

III. Feeds consumed by animals contain plant food elements. A portion of each of these elements is voided by the animal in its feces and urine. The manure contains these valuable fertilizing constituents, namely nitrogen, phosphorus and potassium, and also calcium.

The composition of fresh manure varies with the individual animal, and the nature of the feed consumed. The average composition of fresh manure of different farm animals appears in the following table: *

<i>Animal</i>	<i>Water</i>	<i>Nitrogen</i>	<i>Phosphorus</i>	<i>Potassium</i>
	<i>%</i>	<i>%</i>	<i>%</i>	<i>%</i>
Horse	59	0.70	0.11	0.64
Dairy cattle	79	0.57	0.10	0.52
Fattening cattle	78	0.73	0.21	0.46
Sheep	64	1.44	0.22	1.01
Swine	87	0.50	0.15	0.33
Hen	55	1.00	0.35	0.33

The above figures include bedding, except in the case of the swine and the hen.

1. Compute the number of pounds of nitrogen, phosphorus, and potassium, in one ton of each of the above manures.

Calculate the fertility value of one ton of each manure, at 12 cents per pound of nitrogen, 11 cents per pound of phosphorus, and 8 cents per pound of potassium.

* Ames and Gaither, Ohio Bull. No. 246; Van Slyke, Fertilizers and Crop Production.

2. Compute the number of pounds of calcium in one ton of each of the following manures, if the per cents of calcium are: horse, 0.15%; cattle, 0.18%; sheep, 0.26%; and swine, 0.09%.

3. Analyses of mixed farm manure show an average composition of 0.5% nitrogen, 0.1% phosphorus, and 0.4% potassium. Calculate the number of pounds of each element in one ton of mixed farm manure, and find the fertility value of one ton of manure, at 12 cents a pound for nitrogen, 11 cents a pound for phosphorus, and 8 cents a pound for potassium.

4. 8 tons of manure is the average amount applied to an acre of land. Using the analysis of mixed manure given in problem 3, find the total number of pounds of each element added to the soil by the application of 8 tons of manure.

5. Compute the number of pounds of water in one ton of each of the manures in the table on page 198. (Manures with less moisture are called hot manures, e.g. horse).

COMMERCIAL FERTILIZERS.

Commercial fertilizers are materials which supply plant food elements for the soil. They contain one or more of the elements nitrogen, phosphorus, and potassium. Calcium, and sometimes other elements, are provided in fertilizers. A substance which contains nitrogen is called a nitrogen carrier; one that furnishes phosphorus is a phosphorus carrier, etc. Commercial fertilizers thus have great agricultural value.

Fertilizing materials do not contain the pure elements nitrogen, phosphorus, and potassium. These elements are combined with other elements in the fertilizers. To study the relation between the amount of carrier and the quantity of an element that it contains, use the appropriate formula:

RULE 37. To find the amount of element, the test per cent, or the amount of fertilizer:

- | | |
|--|-----------|
| (a) $\text{Element} = \text{Fertilizer} \times \text{Test \%}$ | $E = FT$ |
| (b) $\text{Test \%} = \text{Element} \div \text{Fertilizer}$ | $T = E/F$ |
| (c) $\text{Fertilizer} = \text{Element} \div \text{Test \%}$ | $F = E/T$ |

Note: For solution of percentage problems, see Chapter XII.

Problems in Fertilizer Materials.

1. Sodium nitrate is a quickly available source of nitrogen. How many pounds of nitrogen are added to the soil, if 125 lb. of nitrate of soda, containing 16% nitrogen, are applied to one acre?

2. Superphosphate (triple) is a good carrier of phosphorus. Find the number of pounds of phosphorus in 250 lb. of treble superphosphate that is 18.8% phosphorus.



Cotton on Poor Norfolk Sand. At Right, no Fertilizer; at Left
1000 Pounds of 5-8-4.

South Carolina Experiment Station.

3. 100 lb. per acre of sulphate of potash were used in vineyard experiments at Mountain Grove, Missouri. How many pounds of potassium were supplied to the acre, if the fertilizer was 39% potassium?

4. Find the number of pounds of (a) phosphoric acid in 1 ton of basic slag of which phosphoric acid is 18%; and (b) potash in 1 ton of muriate of potash that is 48% potash.

Note: The amount of phosphorus in a fertilizer material is usually given in per cent of phosphoric acid (P_2O_5) instead of pure phosphorus. Standard phosphoric acid is 43.7% phosphorus. Likewise, the potassium content is given in per cent of potash (K_2O) instead of pure potassium. Standard potash is 83% potassium.

5. What is the per cent of nitrogen in high grade dried blood, if 500 pounds of this material contain 70 lb. of "N"?

6. If 350 pounds of urea contain 157.5 pounds of nitrogen, find the per cent of nitrogen in urea.

7. How many pounds of sulphate of ammonia must be used to replace 31 lb. of nitrogen that have been lost to the soil? Sulphate of ammonia is 20% nitrogen.

8. Find the number of pounds of bone ash (15% phosphorus) that must be applied to an acre, to replace 64.8 lb. of phosphorus lost to the soil by leaching.

9. A potassium loss of 49.7 lb. due to cropping is replaced by 14% kainit. How much kainit must be used?

10. What is the cost of one pound of potash in manure salts analyzing 30% potash, if the manure salts sell for \$36 per ton?

11. When cyanamid testing 21% nitrogen sells for \$37.80 per ton, what is the cost of one pound of nitrogen in this fertilizer?

MIXED FERTILIZERS.

A complete fertilizer is a mixture containing all three elements, nitrogen, phosphorus, and potassium. As crops and soils may require different amounts of these three elements, fertilizers are mixed in varying per cents of nitrogen, phosphorus and potassium.

The law provides that the analysis of a fertilizer be shown on the container or tag. Manufacturers supply this information by a formula, as 5-8-5. The first number in the formula indicates the per cent of total nitrogen; the second number should represent the per cent of available phosphoric acid; and the per cent of water-soluble potash appears as the last number. In certain instances, these numbers may not indicate

available material. You should become familiar with the requirements of your state.

The laws make no provision for a statement of the per cents of the other elements, such as copper, boron, manganese, etc. Many of these elements are usually supplied by the ordinary fertilizers; sometimes manufacturers add them specifically. However, special attention to these extra elements is rarely necessary.

Composition and Cost of Commercial Fertilizers.

1. 1500 pounds of 5-10-5 fertilizer per acre are recommended for silt-loam soils on Long Island, for the potato crop. Find the quantity of each ingredient in this amount of fertilizer.

METHOD: The analysis indicates 5% N, 10% P_2O_5 , and 5% K_2O .

$$\begin{array}{r}
 1500 \text{ lb.} \\
 \times .05 \\
 \hline
 \text{Answers: } 75 \text{ lb. of N}
 \end{array}
 \qquad
 \begin{array}{r}
 1500 \text{ lb.} \\
 \times .10 \\
 \hline
 150 \text{ lb. of } P_2O_5
 \end{array}
 \qquad
 \begin{array}{r}
 1500 \text{ lb.} \\
 \times .05 \\
 \hline
 75 \text{ lb. of } K_2O
 \end{array}$$

2. The recommendation for a corn crop on a loam soil is 250 pounds per acre of 4-8-4 fertilizer. How much of each ingredient is contained in this quantity of fertilizer?

3. Find the number of pounds of each ingredient in 425 lb. of 3-12-15 fertilizer, used on Michigan soils.

4. 350 pounds of 4-12-4 fertilizer per acre are recommended for the growth of wheat on sandy soils in Ohio. This quantity of fertilizer furnishes how many pounds of each ingredient?

5. Find the fertility value of one ton of 2-8-2 fertilizer, at 11 cents per pound of nitrogen, 5 cents per pound of phosphoric acid, and 6 cents per pound of potash.

6. What is the fertility value of one ton of 6-20-10 fertilizer, at the same values for ingredients as mentioned in problem 5.

7. A firm sells 4-8-12 fertilizer for \$36.70 per ton.

(a) Find the fertility value of one ton of this fertilizer,

at 10 cents per pound of nitrogen, 5 cents per pound of phosphoric acid, and 5 cents per pound of potash.

- (b) How much is charged per ton in excess of the fertility value of the fertilizer?
8. The same firm sells 3-12-18 fertilizer for \$44.80 per ton. (This is a higher analysis fertilizer.)
- (a) What is the fertility value of one ton of this fertilizer, at the values given in problem 7a?
- (b) What is the excess of the selling price above the fertility value of one ton?
- (c) Is this higher analysis fertilizer a better "buy" than the 4-8-12 fertilizer in problem 7?

The Amounts of Elements in Commercial Fertilizers.

See note to problem 4 on page 201.

9. How many pounds each of nitrogen, phosphorus, and potassium are there in one ton of 6-10-7 fertilizer?

METHOD: According to the analysis, one ton contains:

2000 lb.	2000 lb.	2000 lb.
$\times .06$	$\times .10$	$\times .07$
120 lb. of N	200 lb. of P_2O_5	140 lb. of K_2O
	$\times .437$	$\times .83$
	87.4 lb. of P	116.2 lb. of K

10. Find the actual amount of each element N, P, and K in the following quantities of commercial fertilizers:

- (a) 350 lb. of 2-16-2 fertilizer;
 (b) 450 lb. of 4-16-8 fertilizer;
 (c) 150 lb. of 0-8-32 fertilizer;
 (d) 275 lb. of 10-6-4 fertilizer;
 (e) 425 lb. of 0-14-6 fertilizer;
 (f) 175 lb. of 16-20-0 fertilizer.

Low and High-analysis Fertilizers—Units of Plant Food.

One per cent of a ton, or 20 pounds is one unit. Since the numbers in a fertilizer formula represent the number of per cents of nitrogen, phosphoric acid, and potash, these same fig-

ures indicate the number of units of each ingredient. Thus, 3-8-5 fertilizer contains 3 units of nitrogen, 8 units of phosphoric acid, and 5 units of potash. Prices of fertilizers are often compared on the basis of costs per unit.

Ordinary or low-analysis fertilizers are those which contain less than 20 units (20 per cent) of total plant food. The analysis 3-8-5 totals 16 units of plant food, and is a low analysis. If the total number of units of plant food is greater than 20 (20 per cent), the fertilizer has a **high analysis**. The designation **concentrated fertilizers** is used when the plant food totals more than 30 units. 10-16-14 is an illustration of a concentrated fertilizer.

The price of one ton of fertilizer includes the charge for the plant food, and a basic fixed cost, covering labor, freight, overhead, etc. A high-analysis fertilizer contains more plant food and less filler (usually sand) to make up the weight of one ton. The basic cost is approximately the same for low or high-analysis fertilizers, but more units of plant food can be purchased for the same basic cost in high-analysis fertilizers.

1. Find the basic cost of 4-8-4 fertilizer selling for \$30 per ton, at \$2 per unit of nitrogen, \$0.80 per unit of phosphoric acid, and \$1 per unit of potash.

METHOD: Total cost		\$30.00
4 units of N at \$2	\$ 8.00	
8 units of P_2O_5 at \$0.80 ..	6.40	
4 units of K_2O at \$1	4.00	
Total cost of plant food ..	\$18.40	18.40
Basic cost		\$11.60

2. What is the basic cost of a ton of 2-12-6 fertilizer selling for \$31.30 per ton, at \$2 per unit of nitrogen, \$0.90 per unit of phosphoric acid, and \$0.90 per unit of potash?
3. What should be the price of a ton of 4-10-3 fertilizer, if the basic cost is \$14, and the unit costs are \$2.20 for nitrogen, \$0.70 for phosphoric acid, and \$0.80 for potash?



Corn, All Planted at the Same Time. Left to Right: 1st Treated with Material Containing N, 2nd Received N and K, 3rd Received P and K, and 4th Received N, P and K.

4. In a certain locality, the basic cost per ton for fertilizers packed in 200 pound bags is \$12.80, and the costs per unit of plant food are \$2.20 for nitrogen, \$0.70 for phosphoric acid, and \$0.80 for potash.

- (a) Find the cost of one ton of 2-8-2 fertilizer.
- (b) What is the cost of two tons of 2-8-2 fertilizer?
What is the total number of units of plant food supplied in two tons of 2-8-2 fertilizer?
- (c) 4-16-4, a high-analysis fertilizer, is the double strength of 2-8-2. Find the cost of one ton of 4-16-4 fertilizer. What is the total number of units of plant food supplied in one ton of 4-16-4?
- (d) Which is the more economical fertilizer to purchase, 2-8-2 or 4-16-4? Why?

5. It may be necessary to use more expensive materials in the preparation of high-analysis fertilizers. However, compare 5-10-5 fertilizer selling for \$32.04 per ton with 10-20-10 fertilizer selling for \$53.86 per ton, as follows:

- (a) What is the total number of units of plant food in one ton of 10-20-10 fertilizer? Find the cost of one unit of plant food.
- (b) What is the total number of units of plant food in two tons of 5-10-5 fertilizer? What is the cost of one unit of plant food?
- (c) Is 10-20-10 fertilizer more economical than 5-10-5 fertilizer? Why?

Manure as a Mixed Fertilizer.

Average farm manure contains about 0.5 per cent of nitrogen, 0.25 per cent of phosphoric acid, and 0.5 per cent of potash. This is equivalent to a commercial fertilizer which analyzes 0.5-0.25-0.5. Although this is a very low analysis, we must remember the advantages of farm manure, and its comparatively low cost.

Farm manure is an unbalanced fertilizer, because of its low phosphoric acid content. A phosphorus carrier should be used together with manure in order to make it a more balanced fertilizer. In practice, superphosphate may be placed in the barn trenches daily, or the phosphate may be directly added to the soil on which manure is being used.

Converting Manure into a Balanced Fertilizer.

1. One ton of manure is equivalent to 0.5-0.25-0.5 fertilizer. A farmer uses superphosphate, containing 20% phosphoric acid, to raise the analysis to 0.5-1-0.5.

- (a) How many units of phosphoric acid must be added to one ton of manure; how many pounds?
- (b) How many pounds of the superphosphate are needed?

2. 8 tons of manure (0.5-0.25-0.5) are equivalent to one ton of 4-2-4 commercial fertilizer. A farmer wishes to add 4 units of phosphoric acid, in order to produce a more balanced fertilizer, 4-6-4.

- (a) Four units equal what number of pounds?

- (b) How many pounds of superphosphate, which is 16% phosphoric acid, must be added to the manure to provide the additional phosphoric acid?
- (c) Using local prices, compare the cost of one ton of 4-6-4 commercial fertilizer with the cost of 8 tons of manure plus the added superphosphate.

$$\begin{array}{rcccl}
 \text{8 Wagons} & + & \text{400* 20\%} & = & \text{8 Wagons} \\
 \text{8 Tons of Manure.} & + & \text{Superphosphate} & = & \text{X Ton 8-12-8} \\
 & & & & \text{Commercial Fertilizer}
 \end{array}$$

Carefully preserved manure plus superphosphate is an excellent fertilizer. (Mich. Exp. Station Ext. Bull. 71)

Home Mixing of Fertilizers.

1. A home mixture of 2-12-2 fertilizer to be used as soon as mixed is made up of the following materials: ammonium sulphate, containing 20% nitrogen; superphosphate, which is 16% phosphoric acid; and kainit, analyzing $13\frac{1}{3}\%$ potash.

- (a) How many pounds each of nitrogen, phosphoric acid, and potash are required for one ton of the 2-12-2 fertilizer?
- (b) Find how many pounds of each carrier must be used to provide the plant food determined in part (a) of this problem?
- (c) Find the total cost of the mixture, if ammonium sulphate is \$38 per ton, the superphosphate is \$20 per ton, and kainit sells for \$21 per ton. Compare this cost with commercial 2-12-2 fertilizer, selling for \$27.80 per ton.

2. A home mixture of 2-8-8 fertilizer, suggested for corn, small grains, and grasses on soils rich in humus, is made up of the following materials:

	Pounds
Nitrate of soda (16% N)	
Cottonseed meal (5.76% N)	
Superphosphate (16% P_2O_5)	
Muriate of potash (50% K_2O)	
Filler	

(Continued to next page.)

2000 lb.

If 0.8 of the nitrogen is supplied by the nitrate of soda, and 0.2 of the nitrogen is from organic sources (cottonseed meal), find the amount of each material required to make one ton of fertilizer.

SOME CARRIERS OF PLANT FOOD AND PER CENTS OF NUTRIENTS

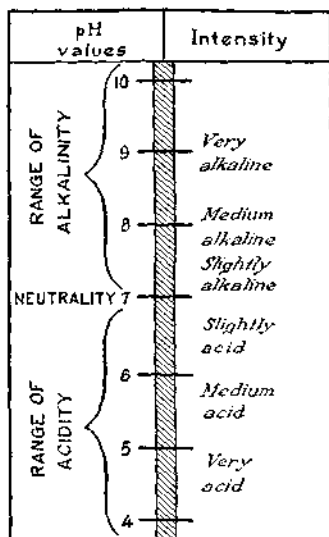
Carriers of N	% of N	Carriers of P_2O_5	% of P_2O_5	Carriers of K_2O	% of K_2O
Nitrate of soda	15.4-16.5	Superphosphate	13.5-22.0	Muriate of potash	47.0-61.5
Ammonium sulphate ...	19.5-21.2	Treble superphos. .	40.0-50.0	Sulphate of potash ..	47.0-52.0
Urea	46.0-46.2	Ground bone.	17.0-30.0	Kainit	14.0-22.0
Dried blood ..	6.0-14.0	Basic slag....	5.0-20.0	Manure salt.	19.0-32.0

Note: Not all carriers can be safely mixed.

THE LIMING OF SOILS.

Liming is a farm practice that dates back thousands of years. Several purposes are served by liming. Limes are fertilizer materials that replace calcium, and also magnesium, that have been lost to the soil by leaching and cropping. Soil acidity is corrected by liming.

Substances are either acid, basic or neutral. Soils contain acid and basic constituents. If these are present in equal quantities, the soil is neutral; if there is a greater amount of acid or basic materials, then the soil is correspondingly called acid or basic. This condition of a soil can be determined by chemical test. It is measured in "pH" units. As shown in the chart at the left, pH 7 represents the measure of a



neutral soil, while alkalinity (basic) increases with measures

more than pH 7, and acidity increases with measures less than pH 7.

Strong acidity is harmful to most crops. The availability of plant food elements is effected, harmful elements are increased, and general soil conditions are impaired. In liming, substances are added which decrease soil acidity. However, soils should not be over-limed, as most crops thrive in soils that are slightly or medium acid. A list of field and garden crops and suitable pH ranges for their growth appears at page 297. Some substances that are used in liming are: limestone, marl, burned lime, hydrated lime, oyster shells, and blast-furnace slag.

1. The Cornell station found that the use of 1500 pounds of burned lime to the acre increased the yield of clover from 2178 to 4343 pounds. What is the net value of this gain, at \$10 per ton of clover hay, and \$10 per ton of liming.

2. At the Ohio station, the following average crop yields per acre were obtained on limed soil in five-year rotation experiments: 46 bu. of corn, 49 bu. of oats, 28 bu. of wheat, 3400 lb. of clover, and 3900 lb. of timothy. On unlimed soil, the average crop yields per acre were as follows: 24 bu. of corn, 36 bu. of oats, 18 bu. of wheat, 1300 lb. of clover, and 1500 lb. of timothy. Find the value of the net loss caused by the failure to use lime, at 50¢ per bu. of corn, 30¢ per bu. of oats, 90¢ per bu. of wheat, \$8 per ton of clover, and \$8 per ton of timothy. The total cost of liming was \$7.50.

The table on p. 210 is a guide to the amounts of material required to change the reaction of soils 1.0 pH, when the organic matter content is average or medium. For soils low in organic content 25 per cent less may be used, but for soils high in organic matter double the amounts (100 per cent more).

3. Using the table on p. 210, determine the amount of liming material needed for the following crops on one acre of soil of average organic matter content:

- (a) Alfalfa:—find amount of hydrated lime to raise sandy loam from pH 6 to pH 7.

- (b) Wheat:—find amount of ground limestone to raise silt loam from pH 5 to pH 6.5.
 (c) Tobacco:—find amount of marl to raise light sandy soil from pH 5 to pH 5.3.
 (d) Cotton:—find amount of burnt lime to raise loam soil from pH 4.8 to pH 6.
 (e) Corn:—find amount of oyster shells to raise clay loam from pH 5.2 to pH 6.1.

Soil Types	Lb. required per acre to raise pH 1 unit		
	Burnt Lime	Hydrated Lime	Limestone, marl or oyster shells
Light sandy	840	1110	1500
Sandy loams	1120	1480	2000
Loams	1680	2220	3000
Silt loams and clay loams	1960	2590	3500

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Chapter XIX

FARM POWER AND MECHANICS

MODERN farming employs a wide variety of machinery for numerous purposes. Make a list of all the implements and machines on a farm. How many of these did the farmer of fifty years ago have? Which of these devices were in use one hundred years ago? To operate these machines, the farmer may utilize man labor, the horse, the gasoline engine, electrical power, and water power.

THE LEVER.

The simplest of all machines is the **lever**. It consists of a rigid rod which can be turned about a fixed point F , called the **fulcrum**. The crowbar used to raise a heavy rock is a lever. You are using a lever when you pull out a nail with a claw hammer, which you could not draw out with your fingers. Name other utensils that are levers.

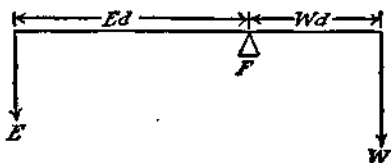
E is the **effort** applied.

W is the **weight** to be moved.

F is the **fulcrum** (the pivot).

Ed is the distance from the effort to the fulcrum.

Wd is the distance from the weight to the fulcrum.



The effort and the weight are the forces acting on the lever. The product of a force by its perpendicular distance from the fulcrum is called the **moment** of the force. When the effort balances the weight, the **moment tending to turn the lever in one direction equals the moment tending to turn the lever in the opposite direction**. If the effort is applied at a greater distance from the fulcrum, it will have a larger mo-

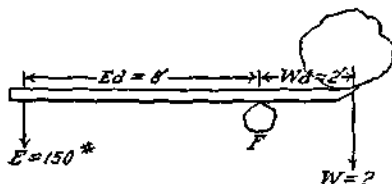
ment. Thus, for example, with a water pump having a long handle, a large pull can be exerted on the piston.

RULE 38. The principle of moments, of the lever.

$$E \times Ed = W \times Wd$$

Problem. A man applies a force of 150 lb. on one end of a crowbar, at a distance of 8 ft. from a small rock used as the fulcrum. How much weight can be raised at the other end of the crowbar which is 2 ft. from the fulcrum?

SOLUTION:



- 1) $E \times Ed = W \times Wd$
 - 2) $150 \times 8 = W \times 2$
 - 3) $1200 = 2W$ (See page 103,
 - 4) $600 = W$ step 3)
- Answer: 600 lb.
Check: $150 \times 8 = 600 \times 2$

Draw a diagram for each of the following lever problems, and solve by using the principle of moments:

1. A man uses a crowbar to lift a stone weighing 1400 lb. If the fulcrum is 1 ft. from the weight and 7 ft. from the effort applied at the other end of the crow bar, how much force must the man exert to raise the stone?
2. A person pushes downward with a force of 15 lb. on a pump handle, at a distance of 24 in. from the pivot. If the piston rod is 5 in. from the pivot, how much force is applied to the piston?
3. A piece of wire is placed in a pair of shears 0.5 in. from the rivet. How much force must be applied on the handles 8 in. from the rivet, to exert a cutting force of 160 lb. on the wire?
4. A force of 15 lb. is applied on a hammer that has a 9-inch handle. How much pull is exerted on a nail which is 2 in. from the fulcrum?
5. The handles of a wheelbarrow are 4 ft. from the axle.

What force must be used on the handles to carry a 300-pound load, if the weight distance is 9 in.?

6. An 8-foot crowbar is used to move a stone. If 1 ft. of the bar is thrust under the stone ($Wd = 1$), how much force is exerted on the stone, when 160 lb. are applied at the other end. Consider the fulcrum at the end of the bar under the stone?

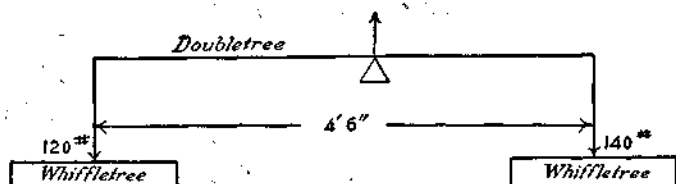
The Doubletree. When two horses are used for the draft of a farm implement, the whiffletree of each horse is attached to a doubletree. The doubletree should be adjusted to compensate for horses having unequal pulls.

Adjusting the Doubletree.

At what point should you attach a doubletree 4 ft. 6 in. long, for two horses weighing 1200 lb. and 1400 lb.

Assume that the steady draft of a horse is about $\frac{1}{10}$ of its weight. Then the heavier horse should be attached to the shorter arm of the lever (doubletree), and the lighter horse should be given the advantage of the longer arm.

SOLUTION:



1200 lb.—120 lb. pull, or $\frac{120}{260}$ part of the load.

1400 lb.—140 lb. pull, or $\frac{140}{260}$ part of the load.

Total pull 260 lb. 4' 6" = 54 in., doubletree.

$$\frac{120}{260} \times 54 = 25 \text{ in.}$$

Answers:

1200 lb. horse, 29 in. from F.

1400 lb. horse, 25 in. from F.

$$\frac{140}{260} \times 54 = 29 \text{ in.}$$

Approximate check:

$$120 \times 29 = 140 \times 25.$$

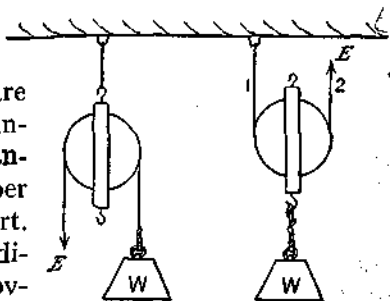
Determine the point at which the doubletree should be attached, for the following teams of horses:

1. 4 ft. 8 in. doubletree; 1400 and 1600 lb. horses.
2. 4 ft. 3 in. doubletree; 1200 and 1600 lb. horses.
3. 4 ft. doubletree; 1300 and 1500 lb. horses.
4. 4 ft. 4 in. doubletree; 1200 and 1500 lb. horses.

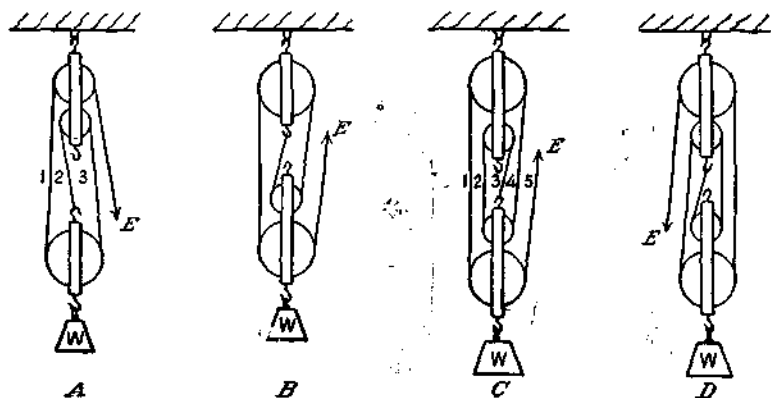
PULLEY SYSTEMS.

Another machine is the pulley system. Blocks of fixed and movable pulleys are used for a mechanical advantage. The **mechanical advantage** of a machine is the number of times it multiplies the effort.

A fixed pulley changes the direction of the rope. The movable pulley at the right has a mechanical advantage of 2, as two ropes support the weight.



The mechanical advantage of a pulley system equals the number of ropes supporting the weight.



If the effort in A is 150 pounds, each of the three ropes supporting the weight carries 150 pounds, and the total number

of pounds that can be raised is 450 pounds. Actually, friction and the weight of the pulley system reduce the amount that can be lifted. As the mechanical advantage of the system in A is three, 200 pounds will raise 600 pounds, 900 pounds of weight can be lifted by an effort of 300 pounds, etc., if we disregard friction and the weight of the machine.

The mechanical advantage of system C is five. Theoretically, an effort of 150 pounds will raise a weight of 750 pounds with this system, one-half ton can be lifted by an effort of 200 pounds, etc.

1. What is the mechanical advantage of system B? Using these pulleys, how much effort is needed (theoretically) to raise a weight of 600 lb.; 800 lb.; 1000 lb.; 1200 lb.?

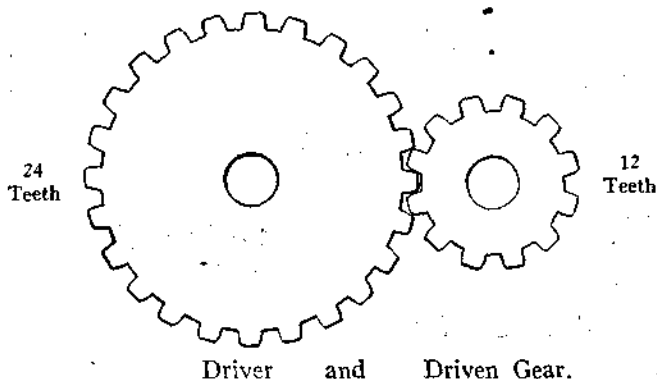
2. What is the mechanical advantage of system D? Using these pulleys, how much weight can be raised (theoretically) by an effort of 100 lb.; 125 lb.; 150 lb.; 225 lb.?

Combinations of Machines.

What we may usually call a single machine on a farm may be a combination of simple machines. Besides the lever and the pulley, other simple machines are the **inclined plane**, which includes the wedge, the **wheel and axle**, such as the steering wheel of a vehicle, and the **jackscrew**. In any case, the mechanical advantage of a simple machine or of a combination of machines equals the distance moved by the effort divided by the distance moved by the weight (resistance).

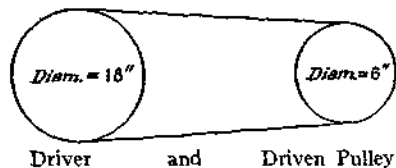
TRANSMISSION OF POWER.

Machines are operated by some kind of power. It may be necessary to transmit the power from its source to the machine. At the same time it may be desirable to change the speed of rotation. **Revolutions per minute** or **R. P. M.** is the measure of the speed of a mechanism. You may want to **step up** the speed or **step down** the speed. **Gears and pulleys** are used for these purposes.

Using gears for the transmission of power.

Sizes of gears are indicated by the number of teeth. If the larger gear in the diagram rotates once, the smaller gear must rotate twice. Thus the 24-tooth gear having 200 R.P.M. will drive the 12-tooth gear at 400 R.P.M., or $24 \times 200 = 12 \times 400$.

RULE 39. The number of teeth $\times$ R.P.M. of the driver = the number of teeth $\times$ R.P.M. of the driven gear.

Using pulleys for the transmission of power.

The size of a pulley is measured by its diameter. You can step up the speed by combining a large driver with a small driven pulley, and speed can be stepped down by using a small driver with a large driven pulley. In the accompanying diagram, the smaller pulley will rotate three times while the larger pulley rotates once, because the circumferences are in the ratio 1:3. If the 18" pulley is running at 150 R.P.M., the speed of the 6" pulley is 450 R.P.M., or $18 \times 150 = 6 \times 450$. The following rule is similar to that for gears:

RULE 40. The diameter $\times$ R.P.M. of the driver = the diameter $\times$ R.P.M. of the driven pulley.

Problems in the Transmission of Power by Gears and Pulleys.

1. **Sample Gear Problem.** If a 38-tooth gear running at 288 R.P.M. is driving a 72-tooth gear, what is the R.P.M. of the driven gear?

$$\begin{array}{ll} \text{Driver: } T = 38 & 1) \ T \times \text{R.P.M.} = T \times \text{R.P.M.} \\ \text{R.P.M.} = 288 & 2) \ 38 \times 288 = 72 \times R \\ \text{Driven: } T = 72 & 3) \ 10,944 = 72 R \\ \text{R.P.M.} = ? & 4) \ 152 = R \end{array}$$

Answer: 152 R.P.M. *Check:* $38 \times 288 = 72 \times 152$.

2. A 69-tooth gear is driving a 30-tooth gear. If the speed of the driver is 60 R.P.M., what is the R.P.M. of the driven gear?

3. A gear of 72 teeth has a speed of 35 R.P.M. Find the number of teeth of a second gear to be driven at 90 R.P.M.

4. **Sample Pulley Problem.** A feed grinder equipped with a 6" pulley is designed to run at 1000 R.P.M. What size pulley must be used on the line shaft (driver) which turns at 250 R.P.M.?

$$\begin{array}{ll} \text{Driver: } D = ? & 1) \ D \times \text{R.P.M.} = D \times \text{R.P.M.} \\ \text{R.P.M.} = 250 & 2) \ D \times 250 = 6 \times 1000 \\ \text{Driven: } D = 6" & 3) \ 250 D = 6000 \\ \text{R.P.M.} = 1000 & 4) \ D = 24 \text{ in. } \textit{Answer.} \\ & \text{Check: } 250 \times 24 = 6 \times 1000. \end{array}$$

5. A 14" pulley on a line shaft running at 240 R.P.M. is used to drive the countershaft of a band saw at 280 R.P.M. What size pulley should be placed on the countershaft?

6. At what speed will a lathe be run if it has a 30" pulley connected by a belt to a 26" pulley on a line shaft running at 90 R.P.M.?

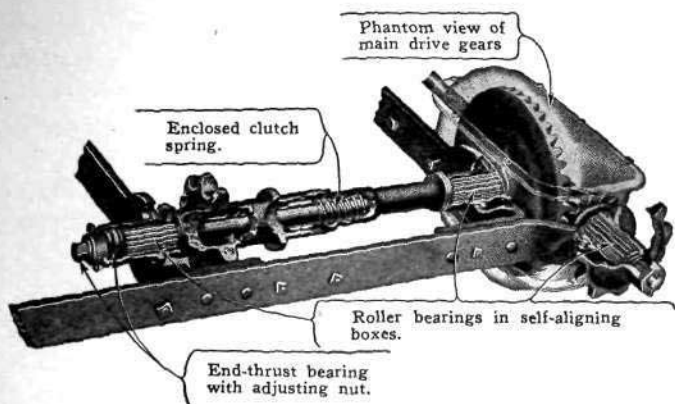
7. What must be the number of teeth of a driver running at 276 R.P.M., to drive a 46-tooth gear at 360 R.P.M.?

8. If a 9" pulley is used on an engine, what should be the speed of the engine, in order to drive a machine at 270 R.P.M.? An 11" pulley is used on the machine.

9. A 168-tooth gear is driving a 28-tooth gear at 492 R.P.M. What is the R.P.M. of the driver?

10. What size pulley should be placed on an engine running at 160 R.P.M., if it is used to drive a machine having a 4" pulley at a speed of 400 R.P.M.

11. Find the R.P.M. of a 56-tooth gear, if it is driven by a 32-tooth gear running at 210 R.P.M.



The Main Drive Gears of a Grain Binder.
Courtesy of John Deere.

WORK and HORSEPOWER.

If a horse pulls against a plow but the plow does not move, the horse does no work in the scientific sense. Work is being done only when a force overcomes resistance.

RULE 41. Work (foot pounds) = force (pounds) $\times$ distance (feet).

If the draft of a plow is 250 pounds and a horse pulls the plow 100 feet, the work done is $250 \times 100 = 25,000$ foot pounds (ft. lb.). The work done by a horse in pulling a two

ton load up a 300-foot incline with a draft of 350 pounds is $350 \times 300 = 105,000$ ft. lb.

The increase in draft of a farm implement results in a greater amount of work. The farmer should attempt to reduce draft to a minimum. He should use well designed and constructed implements, and should keep them properly sharpened, adjusted and lubricated.

Computing Amounts of Work.

1. How much work is done by a horse in plowing a furrow 30 rods long, if the draft of the plow is 375 lb.?

2. What is the quantity of work done by the horse plowing the same furrow of 30 rods, if the draft of the plow is reduced to 360 lb. by proper sharpening of the plowshare?

3. Find the amount of work done by a horse in pulling a wagon with a draft of 220 lb. for a distance of 1 mile.

4. How much work is done by the horse pulling the same load one mile, if the draft is reduced to 200 lb. by greasing the axles of the wagon?

5. The pulley system A, page 216, is used to raise 600 pounds of hay. Disregard friction and the weight of the machine in the following questions.

(a) If the effort required is 200 lb. and 90 ft. of rope must be pulled down to raise the hay to a loft, how much work is put into the machine (input)?

(b) If the 600 lb. of hay is raised 30 ft., how much work is put out by the machine (output)?

(c) What is the relation between the work input and the work output?

Note: Although a machine multiplies the effort, no work is gained through its use.

6. A 1500-pound load must be raised to the top of a hill which is 50 feet high, by use of an incline.

(a) What is the work output of this machine (the inclined plane)?

(b) To perform this task, a draft of 125 pounds is re-

quired along a 600-foot road. What is the work input of the machine? Disregard friction.

- (c) If a gentler grade * were used, 100 pounds of draft would be needed along a 750-foot road. What would be the work input in this case?

POWER is the speed of doing work. It is not only necessary for a horse to perform work, but the work must be done in a convenient length of time. However, you must also be careful not to overwork the horse. James Watt discovered by experiments that a draft horse could raise 150 pounds of coal through a distance of 220 feet in one minute. The work done was 150×220 , or 33,000 foot pounds, in one minute. He called this **one horse power (1 H.P.)**.

RULE 41. To find the number of horse power:

$$\text{Horse power} = \frac{\text{foot pounds per minute}}{33,000}$$

Problem. How much power is developed by a 1600-pound horse when pulling with a draft of 160 pounds ** at a steady rate of 2.5 miles per hour.

SOLUTION: $2.5 \text{ miles} \times 5280 = 13,200 \text{ feet per hour.}$

$$13,200 \div 60 = 220 \text{ feet per minute.}$$

$$160 \text{ lb.} \times 220 \text{ ft.} = 35,200 \text{ ft. lb. per min.}$$

$$\text{H.P.} = \frac{35,200}{33,000} = 1.1 \text{ Horse power. Answer.}$$

Problems in Work and Horsepower.

1. If an 1800-pound horse pulls with a steady draft of 180 pounds, how much power is the horse developing when walking at a rate of 2.3 miles per hour?

* The grade of a road is the measure of its slope. When an engineer states that a road has a 2% grade, he means that there is a 2 foot rise vertically for every 100 feet of horizontal distance. A greater pull is required on a steeper grade, but the distance the load must travel is shorter. To lessen the draft, use a road of gentler grade.

** In general, the horse will do a day's work most efficiently when the steady draft is about one-tenth of his weight, and the continuous speed is 2 to 2.5 miles per hour.

2. Find the number of horsepower that a 1500-pound horse can develop at a continuous speed of 2.4 miles per hour for a full working day, if the steady draft is 150 pounds.

3. How many horsepower are being developed by a 1400-pound horse, walking at the rate of 2.1 miles per hour and exerting a steady pull of 140 pounds?

4. A 1200-pound horse pulls with a force of 120 pounds at the rate of 2.5 miles per hour, for a ten-hour day. How many horsepower does he develop?

5. How many horsepower is a horse developing, when pulling with a steady draft of 80 pounds at a rate of 4.8 miles per hour?

6. A champion team of two horses exerted a pull of 3900 pounds. If they maintained this draft for 50 feet in one minute; how many horsepower would they develop?

7. A tractor pulling a plow travels at 3 miles per hour. How many horsepower does it provide, if the steady draft on the plow is 800 pounds?

8. A draft of 300 pounds is needed to make a 14" furrow on a certain field. How much work is done in plowing a section of the field 42 feet wide and 20 rods long?

METHOD: Width of field = 42 ft. $\times$ 12 = 504 in.

Number of furrows = 504 in. $\div$ 14 = 36.

Length of each furrow = 20 rd. $\times$ 16½ = 330 ft.

Total distance traveled = 36 fur. $\times$ 330 ft., or
11,880 ft.

Work = 300 lb. $\times$ 11,880, or 3,564,000 ft. lb.

9. How much work is done in plowing a section of a field 80 feet wide and 10 rods long with a plow making a 16" furrow, if the draft is 350 pounds?

10. A one acre field is 10 rods wide and 16 rods long. The draft on a plow making a 12" furrow is 200 pounds.

(a) How much work is done in plowing the field?

(b) How many horsepower are required to plow the field in 4 hours?



Courtesy of John Deere.
Gasoline Power. A Tractor Pulling a Two-Bottom Plow.

WATER POWER

Use the following conversion factors:

1 cubic foot of water = 62.5 pounds.

1 gallon of water = 8.34 pounds.

1. An engine is used to pump 8000 gallons of water per hour into a reservoir that is 50 feet above the level of the water supply. Find the number of horsepower required.

METHOD: 8000 gal. of water = $8000 \times 8.34 = 66,720$ lb.
Work in 1 hr. = $66,720 \text{ lb.} \times 50' = 3,336,000'$ lb.
Work in 1 min. = $3,336,000 \div 60 = 55,600$ ft. lb.
 $\text{H.P.} = \frac{55,600}{33,000} = 1.7$ Horsepower. *Answer.*

Note: The pump efficiency should also be taken into consideration.

2. What horsepower engine does a farmer need to raise water 60 feet to a water tank, at the rate of 320 gallons per minute?

3. An engine is required to pump 9000 gallons of water per hour into a reservoir 70 feet above the level of the water supply. How much horsepower is needed?

4. A farmer must fill a water tank that is 55 feet above the level of the water supply. How much horsepower is required to pump 250 gallons of water per min. into the tank?

5. What is the theoretic horsepower developed by a steady stream of water of 260 cubic feet per minute, having a total head (height of water) of 10 feet?

Suggestion: Use 1 cu. ft. of water = 62.5 lb.

6. At a certain water power plant the flow of water is 351 cu. ft. of water per min. How much water horsepower is developed if the head (height of water) is 8 feet?

ELECTRICAL POWER.

Modern farming makes considerable use of electrical power. Milking machines, cream separators, concrete mixers, ensilage cutters, corn shellers, etc., are now run by electricity.

Electrical power is measured in **watts**. One **kilowatt** (kw) equals 1000 watts. The relation between mechanical power and electrical power is as follows:

$$1 \text{ H.P.} = 746 \text{ watts.}$$

$$1 \text{ kw.} = 1.34 \text{ H.P.}$$

The farmer buys electricity by the kilowatt hour, which

means 1 kilowatt supplied for an hour. The ordinary electrical appliance requires a certain number of watts, as a 50-watt lamp, a 400-watt heater, etc. The lamp will consume 50 watt hours in 1 hour, 100 watt hours in 2 hours, etc.; the heater uses 1200 watt hours in 3 hours, etc. **1 kilowatt hour (kw. hr.) equals 1000 watt hours.**

RULE 42. To change watt hours to kilowatt hours, move the decimal point in the number of watt hours three places to the left.

Thus, if the 400-watt heater is used for 6 hours, it will consume 2400 watt hours, or 2.4 kilowatt hours. At 6 cents per kilowatt hour, the cost will be 0.144, or \$0.14.

Problems in the Cost of Electrical Service.

1. A milking machine consumes 2 kw. hr. per cow per month. What is the cost per month of milking 24 cows, at 5 cents per kilowatt hour?
2. A washing machine consumes about 350 watt hr. per person per month. Find the cost of operating the machine for a family of 5 persons, at 4 cents per kilowatt hour.
3. What is the cost of the current used by a 518-watt motor ($\frac{1}{2}$ H.P.) which is run for 35 hours, if the cost of using electrical power is 6 cents per kilowatt hour?
4. At 7 cents per kilowatt hour, what is the cost of the current used by fifteen 50-watt lamps burning for 26 hr.?
5. A company charges the following prices for current:
 - 1st 10 kw. hr., at 7 cents per kw. hr.
 - Next 20 kw. hr., at 6 cents per kw. hr.
 - Next 30 kw. hr., at 5 cents per kw. hr.
 - Next 50 kw. hr., at 4 cents per kw. hr.
 - Over 110 kw. hr., at 3 cents per kw. hr.

Compute the monthly bills for the following amounts used:

- | | | |
|----------------|----------------|-----------------|
| (a) 14 kw. hr. | (e) 44 kw. hr. | (i) 86 kw. hr. |
| (b) 18 kw. hr. | (f) 52 kw. hr. | (j) 105 kw. hr. |
| (c) 27 kw. hr. | (g) 65 kw. hr. | (k) 124 kw. hr. |
| (d) 38 kw. hr. | (h) 78 kw. hr. | (l) 131 kw. hr. |

6. Check the total amount charged on an actual monthly bill for electrical current consumed.

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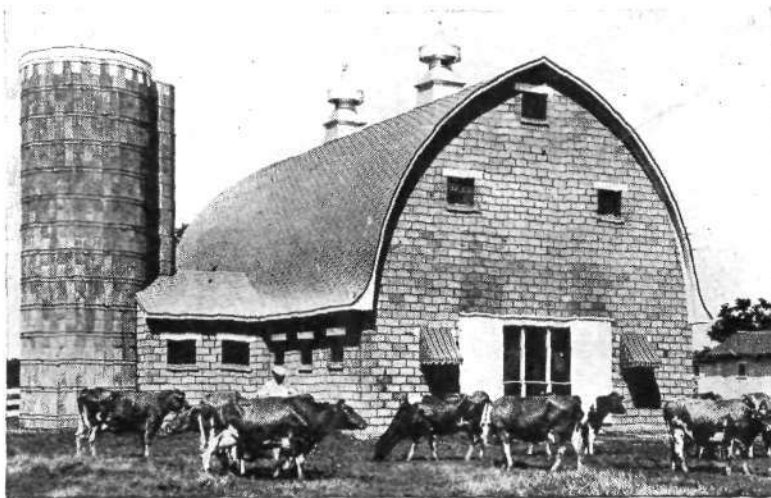
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Chapter XX

CONCRETE CONSTRUCTION

CONCRETE consists of a mixture of cement, sand, gravel, and water. If good quality materials are used and the mixture is properly made, the finished concrete forms a strong and durable substance suitable for various constructions. Concrete is very desirable on farms for building foundations for structures, for cellars, troughs, cribs and bins, barns, milk houses, poultry houses, homes, etc.



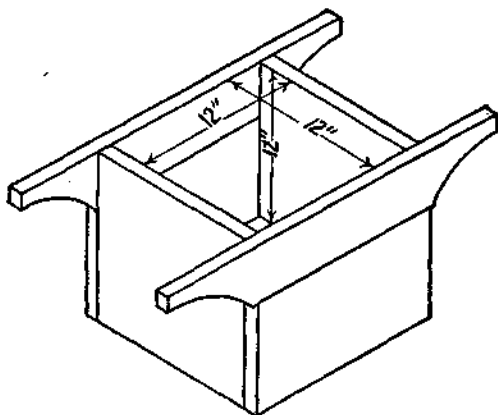
Concrete Silo and Concrete Block Barn.

Concrete Formulas

The proportion of materials in concrete is indicated by a formula of three numbers separated by colons. The first number given in the formula is cement, the second is fine aggregate

(sand), and the third is coarse aggregate (gravel). Thus a 1 : 3 : 5 mix (also written 1-3-5) means a concrete made from 1 part cement, 3 parts sand, and 5 parts gravel.

Cement is purchased in sacks which contain 1 cubic foot, and weigh a little less than 100 pounds. Fine aggregate includes sand, or other fine particles, that will pass through a screen with $\frac{1}{4}$ -inch meshes. Sand should be free from loam, clay and vegetable matter. Coarse aggregate includes all pebbles or broken stone, ranging in size from $\frac{1}{4}$ inch to $1\frac{1}{2}$ or 2 inches. The particles of sand and of gravel should be well graded, in order that the finer particles may fill up the spaces between the larger particles. Aggregates are measured in cubic feet or cubic yards. A pailful can be used as a unit for very small jobs.



A Bottomless Measure for 1 cu. ft. of Aggregate.

Quantities of Material.

With 3 sacks (cu. ft.) of cement, use 9 cu. ft. of sand and 15 cu. ft. of gravel, for 1 : 3 : 5 concrete (the common multiple is 3). If 2 pails of cement are used, mix with 5 pails of sand and 8 pails of gravel, to make 1 : 2.5 : 4 concrete. When 4 cu. ft. of cement, 6 cu. ft. of sand and 12 cu. ft. of gravel are used, the mixing ratio is 1 : 1.5 : 3 (divide by the multiple 4).

1. How many cubic feet each of sand and gravel must be mixed with 2 bags of cement, to make 1 : 2.5 : 3.5 concrete?
2. Compute the number of pails each of sand and gravel that must be added to 3 pails of cement, for a 1 : 3 : 6 mix.

3. If $\frac{1}{2}$ sack of cement is used, what materials must be added for a 1 : 2 : 4 concrete mixture?

4. How many cubic yards each of sand and gravel must be mixed with 9 sacks of cement, to make 1 : 3 : 6 concrete?

Suggestion: What part of 1 cu. yd. is 9 cu. ft.?

5. What is the mixing ratio, when the materials used are: 4 pails of cement, 8 pails of sand, and 8 pails of gravel?

6. If the materials mixed are: 2 sacks of cement, 5 cu. ft. of sand, and 8 cu. ft. of gravel, what formula is used?

7. What is the concrete formula, if the materials are: cement—13.5 sacks; sand—1.25 cu. yd.; gravel—2.5 cu. yd.?



A Mechanical Mixer of Concrete.

Which Concrete Formula to Use.

The proper concrete formula to select depends upon the use to be made of the concrete. The amount of water used per sack of cement controls the strength, watertightness and durability of the concrete. Below are some proportions recom-

mended for several types of work, and the amount of water recommended per sack of cement. It may be necessary to change the amounts of sand and gravel to produce a smooth, plastic, workable mixture. In no event, change the ratio of water to cement from the amounts given in the table.

<i>Type of Work</i>	<i>Gal. of Water</i>	<i>Sacks of Cement</i>	<i>Cu. ft. of Sand</i>	<i>Cu. ft. of Gravel</i>
Pavements, walks, residence floors, etc.	5	1	1	1¾
Fence posts, garden furniture; work of thin sections.	5	1	1¾	2
Watertight floors, basement walls and pits; cisterns and water storage tanks; reinforced concrete	6	1	2¼	3
Foundation walls, retaining walls, engine bases, etc., not subjected to weather, water pressure	7	1	2¾	4

Taken from "Plans for Concrete Farm Buildings," by the Portland Cement Association.

Note: The above quantities of water are to be used with dry sand. If the sand is damp or wet, allowances should be made for the water already present in the aggregate.

How much water should be used with the following amounts of cement?

1. For 1 : 2¼ : 3 concrete—(a) 4 sacks; (b) 9 sacks of cement.
2. For 1 : 1¾ : 2 concrete—(a) 6 sacks; (b) 11 sacks of cement.
3. For 1 : 1 : 1¾ concrete—(a) 7 sacks; (b) 10 sacks of cement.
4. For 1 : 2¾ : 4 concrete—(a) 5 sacks; (b) 8 sacks of cement.

Making the Concrete.

The various ingredients of concrete must be carefully measured, and then thoroughly mixed. Mixing can be done by hand or by machine.

The mixed concrete should be poured into the forms as

soon as possible. Wood is the usual material for the construction of forms. Their inside surfaces should be oiled to prevent the concrete from sticking. Within the forms, the concrete must be "spaded" to release air pockets and to work large particles away from the surfaces of the forms.

The total volume of concrete formed is not equal to the sum of the amounts of cement, sand and gravel mixed. There is a shrinkage, because the cement and sand fill in the spaces between the pebbles. The following table gives the amounts of ingredients that will make 1 cubic yard of concrete of various formulas, under average conditions.

MIXTURES <i>Formulas of the Mortar or Concrete</i>	QUANTITIES OF MATERIALS		
	<i>Sacks of Cement</i>	<i>Cu. yd. of Sand (F.A.)</i>	<i>Cu. yd. of Gravel (C.A.)</i>
1 : 2	12	0.9	...
1 : 3	9	1.0	...
1 : 1 : $1\frac{3}{4}$	10	0.37	0.63
1 : $1\frac{3}{4}$: 2	8	0.52	0.59
1 : $2\frac{1}{4}$: 3	$6\frac{1}{4}$	0.52	0.70
1 : $2\frac{3}{4}$: 4	5	0.52	0.74

Taken from manual of Portland Cement Association.

The first two formulas in the table have only two numbers. Coarse aggregate is omitted. Such mixtures are generally called mortar, and are used for plastering, stucco, top course of floors, and laying masonry units.

Problem. Find the quantity of cement, sand, and gravel, required to make 5 cu. yd. of 1 : $1\frac{3}{4}$: 2 concrete.

METHOD: The following amounts, taken from the table on this page, are needed to make 1 cu. yd. of concrete—

8 Sacks of Cem.	0.52 cu. yd. of F.A.
$\times 5.2$	$\times 5.2$
<u>41.6 Sacks of Cem.</u>	<u>2.704 cu. yd. of F.A.</u>
	0.59 cu. yd. of C.A.
	$\times 5.2$
	<u>3.068 cu. yd. of C.A.</u>

Rounded off to two decimal places, the answers are:

41.6 Sacks of Cem.; 2.70 cu. yd. of sand; 3.07 cu. yd. of gravel.

Compute the ingredients required to make the following quantities of concrete (See table page 232):

1. 8.4 cu. yd. of 1 : 1 : 1¾ concrete.
2. 3.5 cu. yd. of 1 : 2 mortar.
3. 6.7 cu. yd. of 1 : 2¼ : 3 concrete.
4. 5.3 cu. yd. of 1 : 3 mortar.
5. 3¼ cu. yd. of 1 : 2¾ : 4 concrete.
6. 6⅔ cu. yd. of 1 : 2¼ : 3 concrete.
7. 8⅓ cu. yd. of 1 : 1 : 1¾ concrete.
8. 7¾ cu. yd. of 1 : 1¾ : 2 concrete.

Estimate the amount of concrete, and the quantity of cement, sand, and gravel, required for each of the following pieces of work:

9. A sidewalk, 4 feet wide, 60 feet long, and 4 inches thick, is to be made of 1 : 1 : 1¾ concrete.

METHOD: (a) Use the formula for the volume of a rectangular solid. Convert to cubic yards.

$$V = lwh; V = 60 \times 4 \times \frac{1}{3} \times \frac{1}{27} = 2.96 \text{ cu. yd.}$$

- (b) Find the amounts of materials needed by referring to table on page 232 for 1 : 1 : 1¾ concrete.

10 Sacks of Cem.	0.37 C.Y. of F.A.	0.63 C.Y. of C.A.
$\times 2.96$	$\times 2.96$	$\times 2.96$
<u>29.6 Sacks of</u>	<u>1.10 cu. yd. of</u>	<u>1.86 cu. yd. of</u>
Cement.	Sand	Gravel.

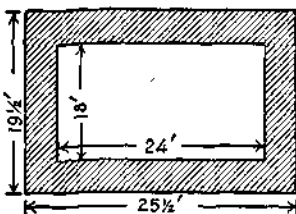
10. A wall, 12 feet high, 35 feet long, and 9 inches thick, is to be made of $1 : 2\frac{3}{4} : 4$ concrete.

11. Use $1 : 2\frac{1}{4} : 3$ concrete for a feeding floor for hogs, 30 feet by 20 feet, and 4 inches thick.

12. Use $1 : 2\frac{1}{4} : 3$ concrete for a barnyard pavement, 50 feet by 40 feet, and 6 inches thick.

13. A driveway, 36 feet long, 7 feet wide, and 6 inches thick, is to be made of $1 : 1 : 1\frac{3}{4}$ concrete.

14. **Estimate for a Foundation.** The foundation is to be made of $1 : 2\frac{3}{4} : 4$ concrete. The inside dimensions of the structure are 24 feet by 18 feet; the walls of the foundation are to be 9 inches thick and 8 feet high.



METHOD: The sketch at the left shows the cross-section of the foundation. The area of concrete equals the inside area subtracted from the outside area. Add two thicknesses of concrete for the outside dimensions. The volume of concrete equals the area of concrete multiplied by the height of the foundation.

(a) Outside length = 24 ft. + 9 in. + 9 in. = 25.5 ft.

Outside width = 18 ft. + 9 in. + 9 in. = 19.5 ft.

(b) Outside area = $25.5' \times 19.5' = 497.25$ sq. ft.

Inside area = $24' \times 18' = 432.00$ sq. ft.

Area of concrete = 65.25 sq. ft.

(c) Volume of concrete = $65.25 \times 8 \times \frac{1}{27} = 19\frac{1}{3}$ cu. yd.

(d) Amounts of materials for $1 : 2\frac{3}{4} : 4$ concrete are:

5 Sacks of Cem.	0.52 C.Y. of F.A.	0.74 C.Y. of C.A.
$\times 19\frac{1}{3}$	$\times 19\frac{1}{3}$	$\times 19\frac{1}{3}$
96 $\frac{2}{3}$ Sacks of Cement.	10.05 cu. yd. of Sand.	14.31 cu. yd. of Gravel.

15. A foundation for a poultry house having inside dimensions 12 feet by 18 feet, is 8 inches thick and 4 feet high, and is made of $1 : 2\frac{3}{4} : 4$ concrete.

16. A foundation is built of $1 : 2\frac{3}{4} : 4$ concrete for a garage having inside dimensions 20 by 22 feet. The foundation walls are 9 feet deep and 9 inches thick.

17. A septic tank is to be made of $1 : 2\frac{1}{4} : 3$ concrete. Inside dimensions are to be: 4 feet width, 10 feet length, and 5 feet depth. All walls, top, and bottom, are to be 4" thick. Suggestion: Find volume of top and bottom. Then compute the volume of the four walls in the same manner as for a foundation.

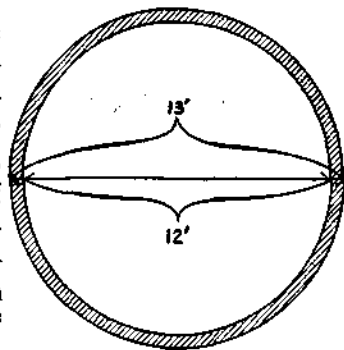
18. Construct a watering trough of $1 : 2\frac{1}{4} : 3$ concrete. Make the inside dimensions as follows: length, 8 ft.; width, 3 ft.; height, 3 ft. The walls are 4 inches thick, and the bottom is 6 inches thick.

19. A foundation for a bull-pen is to be made of $1 : 2\frac{3}{4} : 4$ concrete. The **outside dimensions** of the structure are 12 feet by 18 feet; the walls of the foundation are to be 8 inches thick and 2 feet 6 inches high.

20. **Estimate for a Circular Tank or Silo.** Calculate the amounts of materials needed for the wall of a silo, to be made of $1 : 2\frac{1}{4} : 3$ concrete. The inside diameter is to be 12 feet; the wall is to be 35 feet high and 6 inches thick.

METHOD: At the right is the cross-section of the silo. The area of the concrete equals the inside area subtracted from the outside area. The outside diameter equals the inside diameter plus two thicknesses. The volume of concrete equals the area of concrete times the height. In mathematical shorthand, the volume can be expressed as follows: $V = (\pi R^2 - \pi r^2) h$, if R represents the outside diameter, and r is the inside diameter. This reduces to the formula: $V = \pi(R^2 - r^2) h$.

(a) The outside diameter = $12' + 6'' + 6'' = 13'$.



$$\begin{aligned}
 (b) \quad D &= 13'; \quad R = 6\frac{1}{2}'; \quad R^2 = 169/4 & V &= \pi(R^2 - r^2)h \\
 d &= 12'; \quad r = 6'; \quad r^2 = 36 & V &= \frac{22}{7} \times \frac{25}{4} \times \frac{35}{1} \\
 & R^2 - r^2 = \frac{25}{4} & \pi &= 22/7 & V &= 687.5 \text{ cu. ft.} \\
 & h = 35' & & & V &= 25.46 \text{ cu. yd.}
 \end{aligned}$$

(c) 6.25 S. of C.	0.52 C.Y. of F.A.	0.7 C.Y. of C.A.
$\times 25.46$	$\times 25.46$	$\times 25.46$
159.13 Sacks of Cement.	13.24 cu. yd. of Sand	17.82 cu. yd. of Gravel.

Note. Deduction should be made in the estimate, to allow for intermittent or continuous doors.

To prevent spoilage of silage, diameter and height should be selected so that a 2-inch depth of silage will be fed each day. See table at page 284.

For construction with concrete blocks, calculate volume in the same manner as above, and divide by the volume of one block for the total number of blocks.

21. Estimate the amounts of ingredients for a 1:2¼:3 concrete silo wall, of the following dimensions: inside diameter, 14 feet; height, 42 feet; thickness of wall, 6 inches.

22. Estimate the amounts of ingredients for a concrete silo to be made of 1:2¼:3 concrete. The dimensions are as follows: height, 28 feet; inside diameter, 10 feet; the thickness of wall, 6 inches.

23. A circular tank is to be 10 feet in inside diameter, 7 feet high above its floor, and the walls are to be 6 inches thick. The floor is to be 8 inches thick.

- (a) Find the volume of the wall in cubic feet.
- (b) Find the volume of the floor in cubic feet.
- (c) Compute the total number of cubic yards of concrete required.
- (d) Find the amounts of materials needed for 1:2¼:3 concrete.

24. Follow the same steps of solution as in problem 23 to calculate the amounts of materials for a 1:2¼:3 concrete water tank having the following measurements: inside diameter, 12 feet; inside height, 16 feet; thickness of wall, 6 inches; thickness of floor, 10 inches.

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Chapter XXI

FARM FINANCES—INTEREST

INTEREST is a very large item of expense in the business of farming. If a farmer borrows \$200 from a bank for which he has to repay \$212 at the end of the year, the interest charge is \$12. Often the farmer is paying interest without even realizing that fact. For example, this may occur when merchandise is bought "on credit." Frequently, the actual rate of interest is considerably higher than it appears to be. A study of interest will assist the farmer in minimizing expenditures for that item.

The amount paid for the use of borrowed money is called the **interest**. The **principal** is the amount loaned. The per cent of the principal charged per year is the **rate** of interest. Thus the amount of interest on a loan of \$500 (principal), at 5% (rate), is \$25 per year. If the money is borrowed for a year, the total amount repaid is the principal plus the interest for one year, or \$525.

RULE 43. Interest formulas (for one year):

(a) $\text{Interest} = \text{Principal} \times \text{Rate. } I = P R$

(b) $\text{Rate} = \text{Interest} \div \text{Principal. } R = I/P$

(c) $\text{Principal} = \text{Interest} \div \text{Rate. } P = I/R$

Note: See Chapter XII for the solution of percentage problems.

Compute the interest for one year in the following examples:

<i>Principal</i>	<i>Rate</i>	<i>Principal</i>	<i>Rate</i>
1. \$1500	6%	4. \$8725	4%
2. \$3600	6%	5. \$ 390	3%
3. \$2750	4%	6. \$ 960	3%

<i>Principal</i>	<i>Rate</i>	<i>Principal</i>	<i>Rate</i>
7. \$1775	5%	11. \$ 840	4¾%
8. \$2500	4¼%	12. \$ 1235	5¼%
9. \$3800	5¾%	13. \$ 745	5½%
10. \$7200	3½%	14. \$12,760	3¾%

15. A farmer borrowed \$750, at 4½% interest, for one year. What is the total amount that he must repay at the end of the year? **FORMULA: $A = P + I$**

16. Find the total amount owing on a loan of \$1400 at the end of one year, if the rate of interest is 3¼%.

17. How much must be repaid at the end of one year on a loan of \$1250, at 5½% interest?

18. A bank discounts a farmer's \$800 note, payable in one year. If the bank deducts 4¼% interest, find the net proceeds of the note. **FORMULA: $A = P - I$**

19. Find the net proceeds of a \$750 note, payable in one year, if the rate of bank discount is 5½%.

20. How much did a farmer receive for his own \$625 note, payable in one year, which was discounted at the bank at 4¾% interest?

RULE 44. To find the interest for any number of years, or for a fractional part of a year:

Interest = Principal $\times$ Rate $\times$ Time (in years).

FORMULA: $I = P R T$

Problem I. Find the interest on \$350, at 4½%, for 3 yr.

SAMPLE PLAN $P = \$350$ $I = P R T$

and $R = .045$ $I = \$350 \times .045 \times 3$

METHOD $T = 3$ yr. $I = \$47.25$ Answer.

Problem II. Find the interest on \$640, at 5%, for 90 days.

Solution: Ordinary interest is computed on the basis of 12 months per year of 30 days each, or 360 days in a year. Thus 90 days are 3 months, or ¼ of a year. The interest in this problem equals $\$640 \times .05 \times \frac{1}{4}$. The answer is \$8 interest.

Compute the interest for each of the following examples:

1. \$1325, at 4%, for 5 years.
2. \$820, at 5%, for $3\frac{1}{2}$ years.
3. \$950, at $5\frac{1}{2}$ %, for 2 years.
4. \$625, at $3\frac{1}{4}$ %, for 4 years.
5. \$1640, at $4\frac{3}{4}$ %, for $2\frac{1}{2}$ years.
6. \$740, at 5%, for 2 months.
7. \$925, at 4%, for 6 months.
8. \$1720, at 3%, for 5 months.
9. \$2500, at 4%, for 7 months.
10. \$380, at $3\frac{1}{2}$ %, for 30 days.
11. \$430, at $4\frac{1}{2}$ %, for 60 days.
12. \$2525, at $5\frac{3}{4}$ %, for 30 days.
13. \$1875, at $3\frac{3}{4}$ %, for 60 days.
14. \$550, at $4\frac{1}{4}$ %, for 90 days.
15. \$865, at $5\frac{1}{4}$ %, for 90 days.

Simple Interest and Compound Interest. Interest calculated by the above formulas is called simple interest. If the interest is added to the principal at the end of regular intervals of time, and a new principal is thus formed each time upon which the interest is calculated for each succeeding period of time, the result is compound interest. Interest is thus paid on the interest, and the amount of interest is greater than simple interest at the same per cent. Interest may be compounded annually (by the year), semi-annually (by the half-year), quarter-annually (by the quarter-year), etc. Calculations of compound interest are based upon more difficult formulas. A table is shown at page 298, for the purpose of determining compound interest.

Real Estate Mortgages.

A **mortgage** is a loan to an owner of real property, secured by the property. The **mortgagee** is the person who lends the money. The owner of the property receiving the loan is called the **mortgagor**. Interest on mortgages is calculated in the usual manner by the formula in Rule 44.

Computing Interest on Mortgages.

1. How much interest must be paid quarterly (every quarter-year) on a mortgage of \$6500, at $4\frac{1}{4}\%$ per annum (year)?

2. Find the amount of interest that must be paid quarterly on a \$7200 mortgage, at $5\frac{3}{4}\%$ per annum.

3. A \$4500 mortgage is given on September 15, 1939. How much interest must be paid by the mortgagor to the mortgagee on December 15, 1939, at $4\frac{1}{2}\%$ per annum? How much is the principal, after this payment of interest has been made?

4. A mortgage provides for the repayment of \$6500 by quarterly payments of \$200 principal, and quarterly payments of interest, at $4\frac{1}{2}\%$ per annum. Calculate the first four payments on the mortgage.

Solution: Upon the payment of each installment of principal, the total amount of the mortgage is reduced by \$200. The interest for each succeeding period must be computed on the balance of the mortgage remaining unpaid. Use the following arrangement:

First Payment:

\$6500	Principal ..	\$200.00
$\times .045$	Interest ...	73.13
4) \$292.50	Total ...	\$273.13
		\$73.13

Second Payment:

\$6500	Principal ..	\$200.00
— 200	Interest ...	70.88
\$6300	Total ...	\$270.88
$\times .045$		
4) \$283.50		
		\$70.88

Third Payment:

\$6300	Principal ..	\$200.00
— 200	Interest ...	68.63
\$6100	Total ...	\$268.63
$\times .045$		
4) \$274.50		
		\$68.63

Fourth Payment:

\$6100	Principal ..	\$200.00
— 200	Interest ...	66.38
\$5900	Total ...	\$266.38
$\times .045$		
4) \$265.50		
		\$66.38

5. A \$4000 mortgage must be repaid in quarterly payments of \$250 (principal). The mortgage provides for interest at the rate of 5% per annum, also to be paid quarterly. Find the total amounts of each of the first two payments.

6. Compute the first two payments on a \$6000 mortgage which provides for principal payments of \$300 quarterly, and interest at the rate of 4% per annum, also to be paid quarterly.

7. Calculate the first four payments on a \$4500 mortgage which provides for quarterly payments of \$200 principal, and quarterly payments of interest at the rate of $5\frac{1}{2}\%$ per annum.

8. A \$7000 mortgage provides for quarterly installments of principal of \$350. Quarterly payments of interest are required, at the rate of $4\frac{1}{2}\%$ per annum. Find the total amounts of each of the first four payments.

The Rate of Interest Paid for Store Credit.

Rates of interest vary, for many reasons. Some of the factors determining the rate of interest are: the purpose of the loan, the length of time of the loan, the security for the repayment of the loan, the availability of money for loans, and legal limitations. State laws have established maximum or legal rates, which vary in different states. The charging of more than the legal rate is called **usury**. A typical legal rate is 6%. What is the legal rate of interest in your state?

Suppose you can buy a ton of feed for \$40, paid in cash. However, if you desire one month's credit, that is, one month within which to pay the bill, suppose the cost of the feed is \$41. Then this difference of \$1, which is called a discount for cash, is in reality interest on the \$40 price for one month. Technically the transaction is not considered a loan, and the legal rate of interest does not apply. In practice, it is equivalent to a loan of \$40, for one month, for which \$1 interest is charged. The farmer should calculate the rate of interest, in order to compare with the legal or prevailing rate of interest. Perhaps it may be cheaper for him to borrow the money from a bank, or from another source, instead of purchasing "on credit."

Computation of the rate of interest:

Interest for 1 month = \$1

Interest for 12 months or 1 year = $12 \times \$1 = \12 .

$I = \$12$ $R = I/P$

$P = \$40$ $R = 12/40 = .3$, or 30%, *Answer.*

1. If the price of one ton of fertilizer is \$24, cash, or \$25, on 60 days' credit, what rate of interest is charged for the store credit? (The cash price is the principal.)

2. Find the rate of interest for credit, if the cash price for a farm machine is \$150, and the credit price is \$153.75, to be paid within 30 days.

3. A cattle dealer offers a cash discount of \$10 per cow. If 3 months' credit are available, what is the rate of interest when the credit price for a cow is \$90? (P = cash price.)

4. If the discount for cash is \$4 per \$100, find the rate of interest on a bill of \$250, sold on 60 days' credit.

Payments on the Installment Plan.

1. A farmer can buy a radio for \$50 cash, or by paying \$5 down and \$10 a month for 5 months. What is the rate of interest if he makes the purchase on the installment plan?

SOLUTION:

a) Down payment	\$ 5.00
5 installments, at \$10	50.00
Total Credit Price	\$55.00
Cash Price	50.00
Difference, which is the amount of interest	\$ 5.00

b) As the installments are being paid, the following amounts are owing during each month:

First month	\$ 50.00
Second month	40.00
Third month	30.00
Fourth month	20.00
Fifth month	10.00
Total amount owing for one month	\$150.00

c) The interest on this principal of \$150 is \$5, for one month. The interest for one year would be $12 \times \$5$, or \$60.

$$d) I = \$60$$

$$R = I/P$$

$$P = \$150$$

$$R = 60/150 = .4, \text{ or } 40\%, \text{ Answer.}$$

2. Calculate the rate of interest, if each of the following purchases is made on the installment plan:

(a) Farm machine:—\$175 cash; or \$10 down, and \$35 a month for five months.

(b) Refrigerator:—\$120 cash; or \$15 down, and \$15 a month for 8 months.

(c) Used automobile:—\$450 cash; or \$100 down, and \$40 a month for 10 months.

(d) Cream separator:—\$140 cash; or \$40 down, and \$10 a month for one year.

LOANS are often made providing for repayment on the installment plan. The interest on the full principal is deducted in advance by the lender. However, as payments are made from month to month, the amount of principal decreases. Thus a higher rate of interest is actually being charged than appears on the face of the transaction. The actual rate may be calculated in the same manner as in problem 1, page 243.

3. What is the actual rate of interest on a loan of \$300, which is to be repaid in 12 monthly installments of \$25 each, if 6% interest is deducted in advance?

SOLUTION: a) Face value of loan \$300.00
Interest, 6% of \$300 18.00

Net proceeds \$282.00

b) The following amounts are owing during each month, as the installment payments are being made:

First month	\$ 300.00
Second month	275.00
Third month	250.00
Fourth month	225.00
Fifth month	200.00
Sixth month	175.00

FARM FINANCES—INTEREST

245

Seventh month	150.00
Eighth month	125.00
Ninth month	100.00
Tenth month	75.00
Eleventh month	50.00
Twelfth month	25.00
Total amount owing for one month	\$1950.00

c) The interest on the principal of \$1950 is \$18, for one month. The interest for one year would be $12 \times \$18$, or \$216.

$$\begin{aligned} \text{d) } I &= \$216 & R &= I/P \\ P &= \$1950 & R &= 216/1950 = .111, \text{ or } 11.1\%, \end{aligned}$$

Answer.

4. Compute the actual rate of interest on a loan of \$240, to be repaid in 12 monthly installments of \$20 each, if 5% interest is deducted in advance.

5. How much actual interest is charged for a loan of \$360, which must be repaid in 12 monthly installments of \$30 each, if 4½% interest is deducted in advance?

6. Find the actual rate of interest on a loan of \$500, which is to be repaid in 10 monthly installments of \$50 each, if 5% interest is deducted in advance.

7. A \$200 loan must be repaid in 8 monthly installments of \$25 each. Find the actual rate of interest, if 6% interest is deducted in advance.

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The Cost of Store Credit, by O. H. Maughan. Cornell Extension Bull. No. 349.

Chapter XXII

THE BUSINESS MANAGEMENT OF FARMING

FARMING is a business, and should be managed as a business. The farmer should keep accurate records of all expenses and receipts, the amounts of crops and farm products, etc. Many important conclusions can be derived from the farm records and accounts. Perhaps the crop yields per acre are below average; maybe the returns from the livestock are too low. Is the poultry keeping profitable; is the dairying yielding a satisfactory profit; how much is left for the farmer for his own labor, after deducting all items of expense and interest on capital invested? Through careful analysis of the farm transactions, the farmer can conduct his enterprise on a real business basis.

Inventories.

Suppose you start your farm accounts now. Your first step is to take inventory. The **inventory** is a list of the amounts and values of all farm property. It is the basis of all farm accounts. Inventory should be taken once every year, on the same date. This date may be January 1st, March 1st, April 1st, or any convenient date on which you begin the year's accounting.

The following divisions are advisable in a farm inventory:

Real estate—the farm land, buildings, fences, woodlots, etc.

Livestock—the separate classes of farm animals, as cattle, horses, hogs, poultry, and the like.

Machinery and tools—larger machines and equipment listed separately, and all the smaller items in one group.

Produce, feed, and supplies—number of tons of hay, bushels of oats, etc.

A Sample Farm Inventory

Divisions and Items of Property	April 1, 1938			April 1, 1939		
	Quantity	Value per unit	Valuation	Quantity	Value per unit	Valuation
REAL ESTATE:						
Land and improvements, acres	150	\$70	\$10,500.00	150	\$70	\$10,500.00
LIVESTOCK:						
Dairy cows	8	95	760.00	8	85	680.00
Heifers	3	35	105.00	5	60	300.00
Calves	2	25	50.00	2	25	50.00
Total Cattle			915.00			1030.00
Horses—						
Jim			225.00			200.00
Jack			160.00			155.00
Total Horses			385.00			355.00
Poultry	200	1.30	260.00	220	1.50	330.00
Total livestock			1560.00			1715.00
MACHINERY AND TOOLS:						
Plows, walking, 12"	2	15	30.00	2	12	24.00
Disk harrow	1	60	60.00	1	55	55.00
[List all other items]						
Total machinery and tools			2326.25			2492.00
FARM PRODUCE:						
Oats, bu.	167	.68	113.56	238	.64	152.32
Corn, bu.	70	1	70.00	50	1	50.00
Hay, tons	23	9	207.00	25	9	225.00
Total farm produce			390.56			427.32
PURCHASED FEED AND SUPPLIES:						
Bran, lb.	250	.02	5.00	200	.02	4.00
Fertilizer, tons	9	30	270.00	13	32	416.00
Paris green, lb.	10	.30	3.00			
Cement, sacks				25	.60	15.00
Total feed and supplies			278.00			435.00
NOTES AND ACCOUNTS:						
John Green, for cow			80.00			
Wm. Black, for corn						34.00
Harry Brown, for labor						15.00
Total notes and accounts			80.00			99.00
CASH ON HAND AND IN BANK:			611.00			494.00
Total value of assets			15,745.81			16,162.32
NOTES AND ACCOUNTS OWING:						
Farm mortgage			5,250.00			4,950.00
Henry White, for feed			72.00			
Rich. Gray, for plow						45.00
Total liabilities			5,322.00			4,995.00
SUMMARY:						
Total assets			15,745.81			16,162.32
Total liabilities			5,322.00			4,995.00
Net worth			10,423.81			11,167.32

[Increase of \$743.51 for the year.]

Financial items—cash on hand and in the bank, amounts owing to the farm.

Total assets, or property owned—the sum of the above five divisions. To determine the **net worth**, subtract the liabilities (amounts owed) from this total.

Liabilities—the mortgages, notes, and accounts payable.

1. List the following items of farm produce in inventory form, and calculate the total valuation: Barley—46 bushels, at \$.80; Oats—165 bushels, at \$.65; Corn—116 bushels, at \$1.05; Hay—16 tons, at \$8.75.

2. List the following items of purchased feed and supplies in inventory form, and compute the total valuation: Fertilizer—12 tons, at \$34.70; Lime—16 tons, at \$8.20; Bordeaux mixture powder—35 pounds, at \$.12; Cottonseed meal—12 tons, at \$35.

3. Determine the “net worth” (balance):

Land and improvements—120 acres, at \$110 per acre; Livestock—\$1,203.50; Machinery and tools—\$1,384.25; Farm produce—\$723.84; Purchased feed and supplies—\$346.54; Notes and accounts owed to the farmer—\$198; Cash on hand and in the bank—\$236.80; Notes and accounts owing by the farmer—\$7,354.

4. Compute the “net worth”:

Land and improvements—85 acres, at \$130 per acre; Livestock—\$925.50; Machinery and tools—\$1374.75; Farm produce—\$345.68; Purchased feed and supplies—\$450.50; Notes and accounts owed to the farmer—\$83; Cash on hand and in the bank—\$342.75; Notes and accounts owing by the farmer—\$4580.

5. A mower and hay rake is listed at \$120 in the inventory of April 1, 1939. If with ordinary use of the machine the rate of depreciation is estimated at 10%, what amount should be set down as the valuation of the machine in the inventory of April 1, 1940?

6. An automobile truck is listed at \$450 in the farm inventory of March 1, 1939. At what amount should this item be listed in the inventory of March 1, 1940, if the estimated rate of depreciation is 12%?

Farm Receipts and Expenditures.

Following the inventory, the farmer should keep accurate records of all receipts and expenditures, and all related financial items. At the end of the year, when the next inventory is taken, the "net farm income" and the "net farm profit" can be determined from the totals of the items. The following table distinguishes between receipts and expenses.

Diagram of Farm Receipts and Farm Expenditures.

<i>FARM RECEIPTS</i>	<i>FARM EXPENDITURES</i>
Direct cash receipts: Crop sales. Livestock sales. Sales of junk, etc. Farm equipment sold. Farm supplies sold. Receipts for labor. Receipts for machine hire. Woodlot products sold. Breeding fees received. Sales of junk, etc. Other cash receipts from sale or rent of farm property or in return for work by farm labor.	Direct cash expenditures: Wages paid labor. Board paid out for labor. Livestock purchased. Feed and supplies purchased. Seed, fertilizer, and supplies purchased. Farm equipment bought. Building materials bought. Repairs of farm property. Fuel and oil for farm use. Insurance and taxes. Veterinary, breeding, etc. Other money paid out for farm purposes.
Indirect receipt by inventory: Increased value of farm prop- erty as shown by inventories.	Indirect exp. by inventory: Decreased value of farm prop- erty as shown by inventor- ies.
Indirect receipts by values fur- nished by farm to the personal use of farmer and his family: Value of food and fuel fur- nished by the farm to the farmer. Renting value of dwelling occupied by the farmer and his family.	Indirect exp. by values furnished by the farmer and his family to the farm business: Value of unpaid family la- bor devoted to farm work. Value of unpaid board fur- nished by the farm family to paid farm laborers.

There are a number of methods of keeping these farm records.* Books with specially ruled pages are available for each type of bookkeeping. Whichever method is used, it is important to be able to ascertain readily from the books the separate expenses and returns of each farm department for the year. For example, in one method the page has columns providing for the date, item, and several columns under which the amount is entered according to the department. Receipts may be entered on the right-hand page, and expenditures may be entered on the left-hand page. Some typical departments are: dairying, poultry, crops, orchard.

Determining the Net Farm Income and the Net Farm Profit.

Farm Receipts

Inventory (physical), March 1, 1939	\$11,328.47	
Inventory (physical), March 1, 1938	10,837.42	
Property receipts; inventory increase		\$ 491.05
Financial receipts (including sales for which cash has not yet been received)		2,145.46
Value of food supplied family	\$ 517.26	
Value of fuel furnished family	68.00	
Rental value of dwelling	240.00	
Personal-benefit receipts		825.26
TOTAL FARM RECEIPTS		\$3,461.77

Farm Expenditures

Property expenditures: (none, as there was an inventory increase, not a decrease)		
Financial expenditures (including purchases not yet paid for in cash)		1,624.23
Value of family labor on farm	\$ 270.00	
Value of board for laborers	95.00	
Total personally furnished expenditures ...		365.00
TOTAL FARM EXPENDITURES		1,989.23
NET FARM INCOME		\$1,472.54

* U. S. Department of Agriculture, Farmers' Bull. No. 511.

BUSINESS MANAGEMENT OF FARMING 251

NET FARM INCOME	\$1,472.54
Interest at 5% on total value of physical inventory less value of mortgage, March 1, 1938; \$10,837.42—\$4000 mortgage	\$ 341.87
Value of the farmer's labor	900.00
TOTAL INCOME EARNED by CAPITAL and LABOR	1,241.87
NET FARM PROFIT	\$ 230.67

Notes of explanation. Only physical inventory is considered above; the current unpaid bills are included under expenditures, and the current unpaid sales are included under receipts. Although actual cash is not received by the farmer, personal-benefits must be included as values received. Family labor is an expenditure, although no cash payment may have been made for same.

NET FARM INCOME = TOTAL FARM RECEIPTS minus EXPENDITURES.

Before the year's activities can be considered a profit, deductions must be made for the farmer's labor, and for a 5% interest on his net capital (Physical inventory minus mtge.).

NET FARM PROFIT = NET INCOME minus USE OF CAPITAL and LABOR.

1. Calculate the Total Farm Receipts:

Property inventory, January 1, 1938—\$18,756.23; Property inventory, January 1, 1939—\$20,001.12; Financial receipts—\$2,356.49; Personal-benefit receipts—\$532.73.

2. Calculate the Total Farm Expenditures:

Property inventory, October 1, 1938—\$9,375.82; Property inventory, October 1, 1939—\$9,322.39; Financial expenditures—\$1,358.73; Personally furnished expenditures—\$245.

3. Find the Net Farm Income, and the Net Farm Profit:

Net inventory increase—\$245.20; Financial receipts—\$1,889.45; Personal-benefit receipts—\$530.15; Financial expenditures—\$1,324.61; Personally furnished expenditures—\$210.00; Income earned by capital and labor—\$930.00.

4. Compute the Net Farm Income, and the Net Farm Profit or Loss:

Financial receipts—\$2,380.74; Personal-benefit receipts—\$698.20; Inventory decrease—\$53.50; Financial expenditures—\$1,772.39; Personally furnished expenditures—\$274.00; Income earned by capital and labor—\$1,200.00.

Analysis of the Farm Business.

When the sum of all the charges is deducted from the sum of all the credits, the balance is the net farm income. This balance does not represent all profit. Interest on the farmer's investment (capital) and the value of the farmer's labor must be subtracted from the net farm income, before any part of the net farm income can be considered profit.

A. LABOR INCOME = NET FARM INCOME minus USE OF CAPITAL.

B. RETURN ON CAPITAL = NET FARM INCOME minus FARMER'S LABOR.

The per cent return on capital equals the return on capital divided by the capital. Change the resulting decimal to a per cent.

A. To find Labor Income:		B. To find % Return on Capital:	
Receipts	\$4,563	Receipts	\$4,321
Expenses	2,186	Expenses	2,658
NET INCOME	2,377	NET INCOME	1,663
Capital .	\$23,658	Value of Farmer's	
5% return $\times .05$	1,183	Labor	900
LABOR INCOME	\$1,194		

Note: Labor income is equivalent to the net profit plus the value of the farmer's labor.

RETURN ON CAPITAL \$ 763
 Capital: \$18,140
 $\% = 763/18,140 = 4.2\%$.

How successful has the farm business been for the year? The farmer can answer this question by computing the **labor income** of the farm, and the per cent **return on capital**. He can use these figures as a basis of comparison with other years on his farm, or for comparison with other farms of his type, in the same locality or state.

1. The average of the ten best farms in a section of Florida showed the following accounts: (Florida Bull. No. 175).

Capital—\$9,986; Receipts—\$13,591; Expenses—\$5,064. Compute the labor income, if interest on the capital is calculated at 7%.

2. 83 records of poultry farms on Long Island showed the following returns: (Cornell Bulletin No. 684).

Average capital—\$29,916; Receipts—\$11,890; Expenses—\$8,650. Calculate the labor income, if interest on the capital is computed at 5%.

3. The following is the average financial summary for 100 dairy farms on the coastal regions of Oregon (Oregon Bull. No. 318.): Capital—\$28,020; Receipts—\$5,101; and Expenses—\$2,880. If the interest on capital investment is computed at 5%, find the labor income.

4. The above Florida bulletin records the following averages for 120 farms:

Capital—\$8,111; Receipts—\$3,087; Expenses—\$1,712. Compute the per cent return on capital, if the value of the farmer's labor is estimated at \$750.

5. The above Cornell bulletin averages the returns for 159 poultry farms, as follows:

Average capital—\$19,386; Receipts—\$8,394; Expenses—\$5,938. If the estimated value of the farmer's labor is \$900, what is the per cent return on capital?

6. If the value of the farmer's labor is \$900, find the per cent return on capital for all Oregon dairy farms (above Oregon bulletin). The average financial summary is as follows: Capital—\$22,860; Receipts—\$3,912; Expenses—\$2,314.

STUDIES OF VARIOUS FARM ENTERPRISES.

1. The following figures are averages from accounts in potatoes in New York State:

Costs per acre—growing, \$49.40; harvesting, \$13.06; storing and selling, \$9.15. Total returns per acre, \$110.61.

- (a) Find the total cost per acre.
- (b) What is the total gain per acre?
- (c) The average yield was 156 bushels per acre. Find the cost per bushel, and the return per bushel. What is the profit per bushel?

2. The following averages are from accounts in apples, in New York State:

Costs per acre—growing, \$58.08; harvesting, \$27.59; storing and selling—\$36.77. Total returns per acre, \$150.62.

- (a) What is the total cost per acre?
- (b) Find the total gain per acre.
- (c) If the average yield per acre was 244 bushels, find the cost per bushel, the return per bushel, and the profit per bushel.

3. The following results were obtained in steer fattening experiments in Texas:

Costs per steer—cost into feed lot, \$23.28; feed costs, \$12.11; marketing costs \$4.59. Average market weight of steers, 973 pounds; selling price per hundred weight, \$4.75.

- (a) Find the total cost, the total amount received, and the profit per steer.
- (b) If the initial weight of the steer at the feedlot was 788 pounds, and the final weight at the feedlot was 1037 pounds, find the cost of feed per hundred pounds (cwt.) of gain in feedlot.

4. In Minnesota feeding experiments for fattening lambs, the following results were obtained:

Costs per lamb—initial cost, \$8.65; feed cost, \$2.59; cost of shearing, \$.18. Final weight of fleece, 6.2 lb.; value of wool,

30 cents per lb.; final weight of lamb, 96.4 lb.; net selling price per lamb, \$13.50 per cwt.

- (a) Find the total cost and the total value produced.
- (b) What is the margin (profit) per lamb?

5. In Nevada hog feeding experiments, the following quantities of feeds produced 100 pounds of gain in weight: 322 lb. of barley, 787 lb. of skimmilk, 36 lb. of alfalfa meal. If the labor cost is \$1.47, what is the total cost per hundredweight gain, at the following prices for feed: \$20 per ton of barley, 20 cents per cwt. of skimmilk, and \$10 per ton of alfalfa meal? Find the margin of profit, if hogs sell for \$9 per hundredweight.

6. Compute the cost per 100 pounds of milk and the cost per pound of butterfat from the following figures for dairy farms in Oregon:

4,841 lb. of milk per cow, testing 4.6%.

Annual cost per cow

Total feed	\$28
Labor	22
Use of buildings and equipment	5
Interest on cows and depreciation	8
Miscellaneous	5

Credits

Credit for calves	1
Credit for manure	3
Credit for skimmilk	9

7. Records of certain poultry farms in New York State showed that 895 layers produced 11,216 dozens of eggs, requiring man labor equivalent to 1.5 men.

- (a) Find the number of eggs per hen.
- (b) What is the number of fowls per man?
- (c) How many dozens of eggs were produced per man?

8. A farmer in Pennsylvania "thinned out" 4 acres of woodland. He produced the following from the cut timber:

Logs	\$ 60.00
Material for crates	24.00
Lumber	45.00
Fuel wood	24.00
Sprags (for mine cars)	<u>170.70</u>

The total harvesting, manufacturing, and marketing costs were \$238.10. Find the net profit per acre.

9. A study was made of the cost of operating tractors. The following were the costs per year for operating 10-20 horsepower tractors in New York State:

Fuel and oil	\$84
Depreciation	65
Interest	18
Repairs	15
Farm labor	11
Use of buildings	5
All other costs	<u>5</u>

If each tractor was used for an average of 353 hours per year, what was the cost per hour of operating a tractor?

10. The following were the costs per horse of horse labor, in a study of Oregon farms:

Feed and pasture	\$62.15
Chore labor	8.27
Interest	3.60
Depreciation	11.74
Use of barn	7.81
Harness	3.82
Veterinary, shoeing, medicine	<u>.46</u>

If a horse was used for an average of 753 hours, find the cost per hour of horse labor.

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Selecting a Farm, by E. H. Thomson. U. S. Dept. of Agr. Farmers' Bull. No. 1088.

Forestry and Farm Income, by W. R. Mattoon. (See References, Chap. IX.)

A Method of Analyzing the Farm Business, by Dixon and Hawthorne. U. S. Dept. of Agr. Farmers' Bull. No. 1139.

Farm Budgeting, by J. B. Hutson. U. S. Dept. of Agr. Farmers' Bull. No. 1564.

Business Records for Poultry Keepers, by Johnson and Lee. U. S. Dept. of Agr. Farmers' Bull. No. 1614.

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Liming New York Soils, by A. F. Gustafson. (See References, Chap. XVIII.)

Factors Affecting Costs and Returns in Producing Milk, by L. C. Cunningham. (See References, Chap. XIII.)

Some Results of Farm Cost Accounts, by P. J. Findlen. Cornell Extension Bull. No. 318.

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Factors Affecting Farm Profits in the Williston Area, by Turlington and Hamilton. Florida Agr. Exp. Sta. Bull. No. 175.

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Cost of Horse Labor on Oregon Farms, by Selby, Rodenwald, and Scudder. Oregon Agr. Exp. Sta. Bull. No. 250.

Cost and Efficiency in Prune Production in Western Oregon, by Scudder and Besse. Oregon Agr. Exp. Sta. Bull. No. 292.

Cost and Efficiency in Dairy Farming in Oregon, by Selby, Burrier, and Brandt. Oregon Agr. Exp. Sta. Bull. No. 318.

Steer Fattening Investigations, by Jones, Hall, Jones, and Black. (See References, Chap. XVI.)

Chapter XXIII

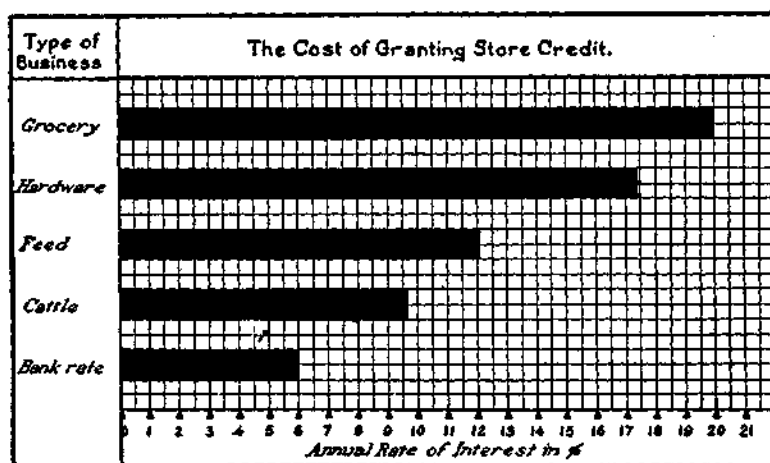
GRAPHS

NUMERICAL data, or statistics, may be pictured mathematically by graphs. Interesting and important relations between numbers may be represented through graphs. Graphs are useful as a form of record-keeping.

The farmer should be able to interpret graphs presented in the numerous agricultural bulletins and publications. He also may desire to draw graphs of certain farm activities. Several types of graphs are explained in this chapter.

Bar Graphs.

The following horizontal bar graph shows the cost of granting credit, computed as an annual rate of interest, in various types of retail stores in New York State.



You should be able to answer the following questions by carefully examining the bar graph on the preceding page. A scale of 2 spaces = 1 per cent has been used for the length of each bar.

- (a) What is the cost in per cent of granting credit by groceries? What is the usual bank rate of interest?
- (b) Estimate the annual rate for hardware retailers; for dealers in feed.
- (c) Find the approximate credit cost, in per cent per year, for cattle dealers.
- (d) About how many times the usual bank rate is the grocer-man's cost of granting credit?
- (e) In what type of retail business is the cost of granting credit the least? Compare this cost with the usual bank rate.
- (f) About how many times the usual bank rate of interest is the cost of granting credit by dealers in feed; by hardware retailers?

How to Make a Bar Graph.

1. Use squared paper.
2. The title may be placed at the top of the graph.
3. Draw a set of axes. These are a pair of perpendicular lines (L-shape) which form a margin on the left and at the bottom of the squared paper.
4. Plan the width per bar and the space between the bars, according to the total amount of space available. Write the names of the bars at the left of the margin for a horizontal bar graph; or at the bottom for a vertical bar graph.
5. Label this axis.
6. Plan the scale for the length of the bars, according to the total amount of space available. Be sure the longest bar will fit on the paper. Write the scale below the axis, for a horizontal bar graph; or at the left, for vertical bars.
7. Label this axis. Be sure to indicate the name of the unit of measurement of the amounts drawn to scale.
8. Draw the bars to scale, and shade the bars.
9. Graphs should be made neatly and accurately.

Check the graph on page 258 for each of the above steps. Use the above outline of procedure for the construction of the graphs for the following data.

1. The table at the right shows for certain states the per cent of all farms that were operated on a farm tenancy basis in 1935, as reported by the United States Department of Agriculture. Draw a horizontal bar graph of these figures.

The per cent of all farms in the United States operated by farm tenants in 1935 was 42%.

PER CENT OF ALL
FARMS OPERATED BY
FARM TENANTS

<i>State</i>	<i>% of Farms</i>
Maine	7
New York	14
Ohio	29
Indiana	32
Kansas	44
Georgia	66

(a) Which of these states

have a higher per cent of farm tenants than the United States as a whole?

(b) Which of these states have a lower per cent of farms operated by farm tenancy than the United States.

2. The wheat yields per acre for the years 1932-1936 appear in the following table (data from the 1938 yearbook, "Agricultural Statistics," of the U. S. Dept. of Agr.) Draw a vertical bar graph representing these figures.

WHEAT YIELDS
PER ACRE

<i>Year</i>	<i>Bu. per Acre</i>
1932	13.1
1933	11.2
1934	12.1
1935	12.2
1936	12.8

(a) What has been the trend in wheat production since the year 1933?

(b) Compare the average returns per acre, at the following prices per bushel: 1932—38.2 cents; 1933—74.4 cents; 1934—84.8 cents; 1935—83.2 cents; 1936—99.7 cents.

3. The United States Department of Agriculture publication, "Crops and Markets," October 1938 issue, reported the following average number of eggs laid daily per farm flock (excluding flocks numbering 400 or more of laying age):

January	17.8	May	39.4	August	24.2
February	25.3	June	34.0	September	20.7
March	32.5	July	28.2	October	18.3
April	42.5				

Arrange this data in a table. Draw a horizontal bar graph.

4. A farmer made the following returns per hour of labor on livestock:

Dairy cows	26 cents	Feeder lambs	72 cents
Hens	14 cents	Sheep	2 cents
Raising chicks	46 cents	Hogs	4 cents

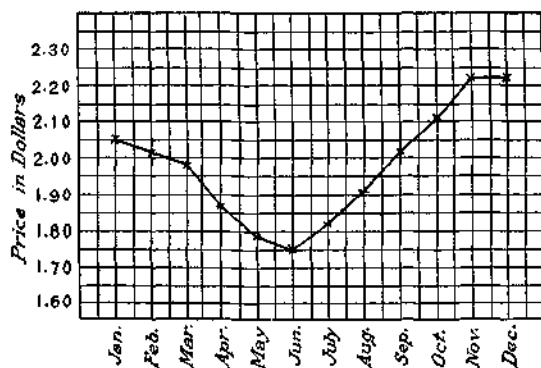
Arrange these figures in a table in order of the amount of return. Draw a vertical bar graph.

Broken Line Graphs.

In a broken line graph, the sets of figures are represented by points on squared paper instead of bars. Straight lines are then drawn between successive points. The broken line that results is the graph.

The following graph, which shows the monthly fluctuations in the average price per hundred pounds of milk, received by farmers in the United States for the year 1937, is an illustration of a broken line graph: (Agr. Stat., 1938.)

Prices Received for Milk in 1937



Months in the Year 1937

MILK PRICES
PER 100 lb.

Month	Price
Jan.	\$2.05
Feb.	2.02
Mar.	1.98
Apr.	1.87
May	1.79
June	1.75
July	1.82
Aug.	1.91
Sept.	2.02
Oct.	2.11
Nov.	2.22
Dec.	2.22

Note: A scale in a bar graph begins from the number zero.

Scales in broken line graphs may commence from any convenient number.

A bar covers the full width of one or two spaces. In broken line graphs, a single point is used for each set of figures.

1. The table below gives the average number of hundred pounds of milk sold by a group of New York farms during the last 10 months of 1936. (Cornell Bulletin Number 698). Draw a broken line graph representing these figures.

Month	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Cwt. of milk	170	174	192	184	139	126	144	160	155	175

2. The normal rate of growth of male Bronze turkeys is shown in the following table. (Kentucky Circular Number 275.) Draw a broken line graph picturing this information.

Age in weeks	4	8	12	16	20	24	28
Weight in lb.	0.9	3.1	6.6	10.3	14.5	18.3	21.4

(a) Determine from the graph the proper weight of a turkey 18 weeks old.

3. A farmer has kept the following record of his average crop yields per acre of corn. Draw a broken line graph showing these figures.

Year	1933	1934	1935	1936	1937	1938
Bu. of Corn per Acre	28	21	32	30	36	33

4. Crop yields vary with the amount of precipitation, that is, the quantity of rainfall, as shown in the table. (Colorado Tech. Bull. No. 25.) Draw a broken line graph showing this relationship.

AVERAGE YIELDS OF
BARLEY IN RELATION
TO PRECIPITATION

Annual Precip.	Crop Yield of Barley
23.1 in.	31 bu.
18.5	29
15.5	10
11.6	3

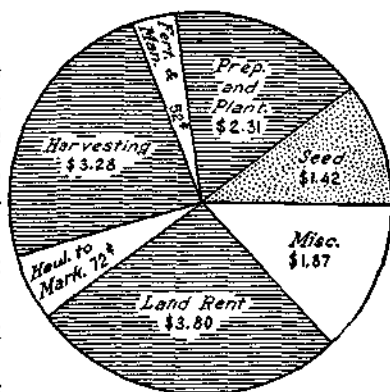
(a) From the graph, find the

average yield for an annual precipitation of 17 in.

- (b) Use the graph to determine the probable amount of rainfall for a 30-bu. yield.

Circle Graphs.

The circle graph at the right shows the factors of cost in the production of one acre of oats, averaging 30 bushels, in the United States. (Agricultural Statistics, 1937).



- Which is the greatest item of cost?
- Which is the smallest item of cost?
- About what fraction of the total cost is the cost of harvesting?
- About what portion of the total cost is the cost of preparing and planting?
- What is the total number of degrees at the center of the circle?
- About what fractional part of the circle is used for the miscellaneous costs? Approximately how many degrees are used for this cost?

Method of Making a Circle Graph.

The above graph is a picture of the information in the table shown here. The number of degrees is determined as follows:

There are 360 degrees for \$13.92. Therefore, there are $360/13.92$, or about 25.9°, for \$1.

For \$1.42, use $1.42 \times 25.9 = 37^\circ$, etc.

Items of Cost	Amount	Degrees of Angle
Seed	\$1.42	37°
Prep. and Plant.	2.31	60
Fert. and Man.	0.52	13
Harvesting . . .	3.28	85
Haul. to Market	0.72	19
Land rent	3.80	98
Miscellaneous . .	1.87	48
Totals	\$13.92	360°

Check for a total of 360° . Rounding off may cause a slight error.

Draw a circle of convenient radius. Construct by means of a protractor the consecutive central angles for the various items. Label each sector of the circle, and shade.

1. A farmer's records showed that his costs of producing 100 pounds of milk were as follows: Feed—\$1.03; Man labor—\$.61; Depreciation on cows—\$.08; Miscellaneous—\$.28.

Draw a circle graph picturing this information. Arrange the data in a table such as appears at the bottom of the previous page.

2. The average cost of producing 1 pound of Oregon prunes, dried and delivered, is approximately as follows: Labor—2.5 cents; Materials and Machinery—0.5 cents; General expense—1.25 cents; Interest—1.75 cents.

Draw a circle graph showing this distribution of cost. Use a table for these figures and for the calculated number of degrees.

3. The per cents of farms in the United States yielding certain net returns in a recent year are as follows:

\$3000 or more	3.84%
\$2000 to \$2999	5.31
\$1000 to \$1999	18.79
\$0 to \$999	63.05
A loss	9.01
	100.00%

Draw a table of the information, and construct a circle graph. Suggestion: The number of degrees may be computed directly by taking the respective number of per cents of 360 degrees.

4. A study in New York of the average rate of milk production of cows in Orange County showed the following figures:

<i>Milk Produced Per Cow</i>	<i>Per Cent of Herds</i>
4000 to 4999 lb.	5%
5000 to 5999 lb.	14
6000 to 6999 lb.	22
7000 to 7999 lb.	38
8000 to 8999 lb.	14
9000 to 9999 lb.	6
10,000 to 10,999 lb.	1

(Cornell Bulletin No. 307).

Draw a table, and construct a circle graph. Calculate the number of degrees directly from the per cents.

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Bulletins:

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A Graphic Summary of the Value of Farm Property, by Stauber and Regan. (See References, Chap. XXI.)

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Agricultural Loans of Commercial Banks, by N. J. Wall. (See References, Chap. XXI.)

Apple Prices, by P. S. Williamson. (See References, Chap. XII.)

Factors Affecting Costs and Returns in Producing Milk, by L. C. Cunningham. (See References, Chap. XIII.)

A Basis for Rating the Productivity of Soils on the Plains of Eastern Colorado, by L. A. Brown. Colorado Agr. Exp. Sta. Tech. Bull. No. 25.

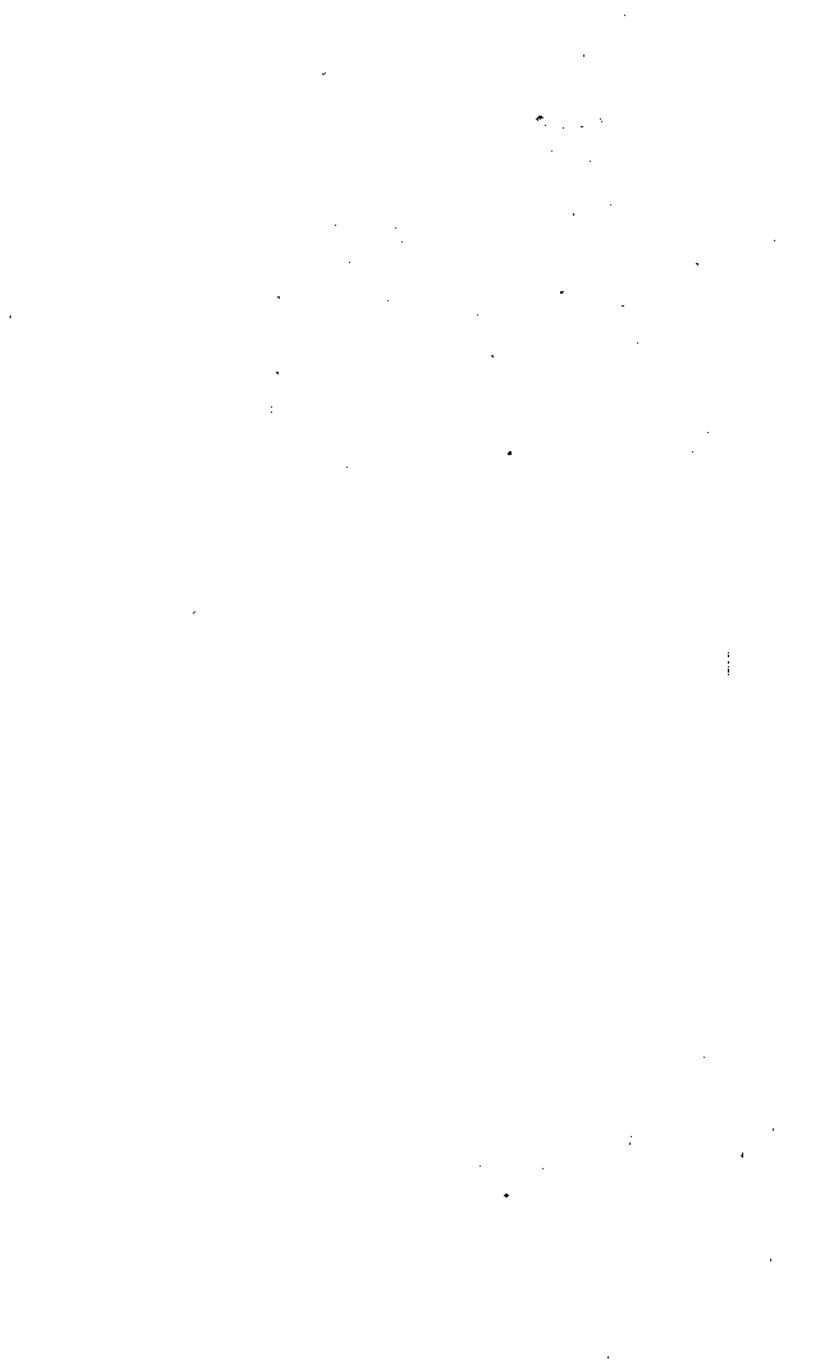
Profitable Turkey Management, by J. H. Martin. (See References, Chap. XVI.)

Fertilizers, by Millar and Turk. (See References, Chap. XVII.)

Farm Tenancy and Rental Contracts in North Dakota, by Miller and Brown. (See References, Chap. XII.)

Cost and Efficiency in Dairy Farming in Oregon, by Selby, Burrier, and Brandt. (See References, Chap. XXII.)

Cost of Producing Turkey Hatching Eggs in Oregon, by Burrier, Knowlton, and Selby. Oregon Agr. Exp. Sta. Bull. No. 333.



APPENDIX

SPECIAL ARITHMETIC DRILLS

General Directions. The following exercises in fractions, decimals, etc., will improve both your accuracy and your speed in computations. Use each of the drills in the following manner:

1. Study the samples at the beginning of each drill.
2. Do all the examples of the drill. (**Do not write in this book**).
3. Check your work by comparing with the answers at the back of the book.
4. Work out again any examples for which you have the wrong answers.
5. When you have done each example of the drill correctly, you have completed the drill.

SPECIAL DRILL NUMBER 1. Addition of Fractions.

$$\begin{array}{r|l} \text{SAMPLE. Add:} & 24\frac{3}{4} \quad \frac{9}{12} \\ & 47\frac{2}{3} \quad \frac{8}{12} \\ \hline \text{Answer} & 72\frac{5}{12} \quad 1\frac{5}{12} = 1\frac{5}{12} \end{array}$$

Explanation: Add the fractions first as a separate example. In order to combine the fractions $\frac{3}{4}$ and $\frac{2}{3}$, you must change them into fractions having the same denominator. The lowest common denominator for these two fractions is 12. This is the smallest number into which each denominator can be divided evenly. To change $\frac{3}{4}$ to twelfths, multiply both numerator and denominator by 3; the common multiplier for the numerator and the denominator of $\frac{2}{3}$ is the number 4. Add $\frac{9}{12}$ and $\frac{8}{12}$, and then reduce the total to $1\frac{5}{12}$. Finally, add 24, 47, and $1\frac{5}{12}$.

Special Drill No. 1. Add the following fractions:

- | | | | | |
|---|---|---|---|--|
| 1. $9\frac{1}{2}$
<u>$4\frac{1}{4}$</u> | 2. $12\frac{3}{4}$
<u>$8\frac{1}{8}$</u> | 3. $16\frac{2}{3}$
<u>$22\frac{1}{4}$</u> | 4. $14\frac{3}{8}$
<u>$7\frac{1}{2}$</u> | 5. $25\frac{3}{4}$
<u>$37\frac{1}{2}$</u> |
| 6. $13\frac{7}{8}$
<u>$28\frac{1}{4}$</u> | 7. $25\frac{3}{4}$
<u>$57\frac{1}{3}$</u> | 8. $61\frac{3}{8}$
<u>$13\frac{2}{3}$</u> | 9. $53\frac{3}{4}$
<u>$47\frac{2}{5}$</u> | 10. $74\frac{5}{8}$
<u>$25\frac{2}{3}$</u> |

SPECIAL DRILL NUMBER 2. Subtraction of Fractions.

SAMPLES.

a) Subtract:	b) Subtract:
$\begin{array}{r} 27\frac{2}{3} \\ - 12\frac{1}{8} \\ \hline \end{array}$	$\begin{array}{r} 2 \\ 32\frac{3}{5} \\ - 18\frac{2}{8} \\ \hline \end{array}$
$\begin{array}{r} 10\frac{1}{24} \\ 3\frac{1}{24} \\ 13\frac{1}{24} \\ \hline \end{array}$	$\begin{array}{r} 9\frac{1}{15} + 15\frac{1}{15} = 24\frac{1}{15} \\ 10\frac{1}{15} \\ \hline \end{array}$
Answer $15\frac{13}{24}$	Answer $14\frac{14}{15}$

Explanation: a) Change the fractions into fractions having the same denominator. The lowest common denominator is 24, and $\frac{2}{3} = \frac{16}{24}$, $\frac{1}{8} = \frac{3}{24}$. Subtract the fractions, and then subtract the whole numbers.

b) The number 15 is the lowest common denominator for the fractions $\frac{3}{5}$ and $\frac{2}{8}$. Change these fractions to $\frac{9}{15}$ and $\frac{10}{15}$, respectively. However, $\frac{10}{15}$ cannot be subtracted from $\frac{9}{15}$. Thus it is necessary to borrow 1 unit from the whole number 33, changing 33 to 32. This unit equals $\frac{15}{15}$. Add $\frac{15}{15}$ to the fraction $\frac{9}{15}$, and the fraction in the minuend becomes $\frac{24}{15}$. From $\frac{24}{15}$ subtract $\frac{10}{15}$, and from 32 subtract 18.

Special Drill No. 2. Subtract the following fractions:

- | | | | | |
|--------------------|--------------------|--------------------|--------------------|---------------------|
| 1. $25\frac{3}{4}$ | 2. $31\frac{5}{8}$ | 3. $17\frac{3}{4}$ | 4. $42\frac{4}{5}$ | 5. $54\frac{7}{8}$ |
| $- 12\frac{1}{2}$ | $- 26\frac{1}{4}$ | $- 9\frac{1}{3}$ | $- 21\frac{1}{2}$ | $- 29\frac{2}{3}$ |
| 6. $34\frac{3}{8}$ | 7. $26\frac{1}{2}$ | 8. $51\frac{2}{3}$ | 9. $32\frac{2}{5}$ | 10. $40\frac{3}{8}$ |
| $- 20\frac{3}{4}$ | $- 11\frac{7}{8}$ | $- 28\frac{3}{4}$ | $- 17\frac{5}{8}$ | $- 25\frac{7}{8}$ |

SPECIAL DRILL NUMBER 3. Multiplication of Mixed Numbers.

SAMPLES.

Multiply:

a) $18 \times 5\frac{1}{2} = 45$. Answer
b) $15 \times 5\frac{1}{2} = 15 \times 11\frac{1}{2} = 165\frac{1}{2} = 82\frac{1}{2}$. Answer
c) $22 \times 4\frac{3}{8} = 11 \times 8\frac{5}{4} = 96\frac{5}{4} = 24\frac{1}{4}$. Answer.

Explanation: Reduce the mixed number to an improper fraction, and then multiply by this fraction. After cancelling, where possible, multiply by the numerator of the fraction and divide this product by the denominator.

Special Drill No. 3. Multiply the following:

- | | |
|-----------------------------|------------------------------|
| 1. $24 \times 5\frac{1}{2}$ | 6. $14 \times 16\frac{1}{2}$ |
| 2. $5 \times 16\frac{1}{2}$ | 7. $16 \times 33\frac{3}{4}$ |
| 3. $12 \times 3\frac{1}{8}$ | 8. $32 \times 4\frac{1}{8}$ |
| 4. $7 \times 5\frac{1}{2}$ | 9. $18 \times 6\frac{3}{4}$ |
| 5. $36 \times 2\frac{3}{8}$ | 10. $26 \times 2\frac{5}{8}$ |

SPECIAL DRILL NUMBER 4. Cancellation.

SAMPLE. Cancel:

$$\frac{\overset{11}{\cancel{55}} \times \overset{4}{\cancel{20}}}{\underset{3}{\cancel{2}} \times \underset{3}{\cancel{15}}} = \frac{44}{3} = 11\frac{1}{3} \text{ Answer}$$

Explanation: Divide any factor of the numerator and any factor of the denominator by the same number, as many times as possible. 55 divided by 5 equals 11; 15 divided by 5 equals 3, etc. Multiply the quotients in the numerator, and the quotients in the denominator. If the answer is an improper fraction, reduce it to a mixed number.

Special Drill No. 4. Cancel the following:

- | | |
|-------------------------------------|---|
| 1. $\frac{18 \times 11}{2}$ | 6. $\frac{30 \times 46}{2 \times 160}$ |
| 2. $\frac{12 \times 32}{3}$ | 7. $\frac{25 \times 60}{2 \times 9}$ |
| 3. $\frac{21 \times 4}{9}$ | 8. $\frac{82 \times 8}{2 \times 160}$ |
| 4. $\frac{50 \times 12}{160}$ | 9. $\frac{70 \times 35}{7 \times 8}$ |
| 5. $\frac{36 \times 7}{2 \times 9}$ | 10. $\frac{26 \times 75}{10 \times 16}$ |

SPECIAL DRILL NUMBER 5. Multiplication of fractions.

SAMPLE.

Multiply:

$$12\frac{3}{4} \times 4\frac{2}{3} = \frac{49}{\cancel{4}} \times \frac{\overset{7}{\cancel{14}}}{3} = \frac{343}{6} = 57\frac{1}{6} \text{ Answer}$$

Explanation: Reduce the mixed numbers to improper fractions. Then use cancellation. The product of the resulting numerators is the numerator of the answer, and the product of the denominators is the denominator of the answer. If the final result is an improper fraction, reduce it to a mixed number.

Special Drill No. 5. Multiply the following:

- | | | |
|--------------------------------------|--|--|
| 1. $\frac{3}{8} \times \frac{5}{6}$ | 5. $7\frac{1}{2} \times 6\frac{2}{3}$ | 8. $8\frac{3}{4} \times 9\frac{1}{3}$ |
| 2. $\frac{3}{4} \times \frac{2}{3}$ | 6. $8\frac{2}{3} \times 4\frac{1}{4}$ | 9. $10\frac{5}{8} \times 3\frac{5}{6}$ |
| 3. $5\frac{1}{4} \times \frac{2}{3}$ | 7. $3\frac{1}{8} \times 12\frac{2}{5}$ | 10. $17\frac{1}{2} \times 14\frac{2}{3}$ |
| 4. $\frac{5}{8} \times 3\frac{1}{5}$ | | |

SPECIAL DRILL NUMBER 6. Cancellation of Fractions.

SAMPLE.

$$\text{Multiply: } \frac{\cancel{27}^{11}}{\cancel{27}^3} \times \frac{9}{2} \times \frac{9}{2} \times \frac{\cancel{27}^3}{\cancel{27}^1} = \frac{2673}{2} = 1336\frac{1}{2} \text{ Answer}$$

Explanation: Use the number 1 as the denominator, for any of the factors that are whole numbers. You may divide the numerator of any fraction and the denominator of any fraction by the same number (cancellation). Multiply the resulting numerators, and the denominators. If the answer is an improper fraction, reduce it to a mixed number.

Special Drill No. 6. Multiply by cancellation:

- | | | |
|---|--|---|
| 1. $\frac{2}{1} \times \frac{22}{7} \times \frac{35}{2}$ | 2. $\frac{1}{3} \times 16 \times \frac{9}{4}$ | 3. $\frac{22}{7} \times \frac{21}{2} \times \frac{21}{2}$ |
| 4. $\frac{1}{2} \times \frac{8}{3} \times 15$ | 5. $\frac{8}{3} \times 10 \times \frac{15}{4}$ | 6. $21 \times \frac{7}{2} \times \frac{16}{3}$ |
| 7. $\frac{13}{6} \times \frac{33}{4} \times \frac{14}{1}$ | 8. $\frac{22}{3} \times \frac{9}{2} \times \frac{17}{4}$ | |
| 9. $\frac{22}{7} \times \frac{15}{2} \times \frac{15}{2} \times 28$ | 10. $\frac{22}{7} \times \frac{35}{4} \times \frac{35}{4} \times 32$ | |

SPECIAL DRILL NUMBER 7. Division by a Fraction.

SAMPLES.

$$\text{Divide: } \quad \text{a) } \frac{3}{4} \div \frac{12}{5} = \frac{3}{4} \times \frac{5}{\cancel{12}^4} = \frac{5}{16}$$

$$\text{b) } 24 \div 16\frac{1}{2} = 24 \div \frac{33}{2} = 24 \times \frac{2}{33} = \frac{16}{11} = 1\frac{5}{11}$$

Explanation: Change the mixed numbers to improper fractions. Then invert the divisor (the fraction that follows the division sign). Now proceed by cancellation as in multiplication of fractions. Thus, to divide by $1\frac{1}{2}$ is equivalent to multiplying by $\frac{2}{3}$, etc.

Special Drill No. 7. Find the quotients:

- | | |
|-------------------------------------|---------------------------------------|
| 1. $5\frac{1}{8} \div 1\frac{1}{3}$ | 6. $36 \div 16\frac{1}{2}$ |
| 2. $3\frac{1}{8} \div \frac{7}{2}$ | 7. $3\frac{3}{8} \div 5\frac{1}{2}$ |
| 3. $66 \div 5\frac{1}{2}$ | 8. $2\frac{7}{4} \div 16\frac{1}{2}$ |
| 4. $22 \div 16\frac{1}{2}$ | 9. $7\frac{2}{3} \div 9\frac{1}{3}$ |
| 5. $40 \div 5\frac{1}{2}$ | 10. $13\frac{3}{4} \div 6\frac{3}{4}$ |

SPECIAL DRILL NUMBER 8. Multiplication of Decimals.

SAMPLES.

a) Multiply:

$$\begin{array}{r} 34.7 \\ .52 \\ \hline 694 \\ 1735 \\ \hline 18.044 \text{ Ans.} \end{array}$$

b) Multiply:

$$\begin{array}{r} .18 \\ .18 \\ \hline .144 \\ 18 \\ \hline .0324 \text{ Ans.} \end{array}$$

Explanation: Multiply the numbers as if without decimals. Point off in the answer as many decimal places as there are in both the multiplicand and the multiplier. Prefix zeros when needed to supply the proper number of decimal places.

Special Drill No. 8. Multiply the following:

- | | | | | |
|------------------------|-------------------------|--------------------------|-------------------------|---------------------------|
| 1. 2.8
<u>.36</u> | 2. 5.9
<u>7.3</u> | 3. 9.6
<u>9.6</u> | 4. 3.74
<u>.52</u> | 5. 26.3
<u>9.4</u> |
| 6. $.23$
<u>.23</u> | 7. $.645$
<u>8.7</u> | 8. 3.46
<u>3.46</u> | 9. $.073$
<u>.14</u> | 10. $.036$
<u>.083</u> |

SPECIAL DRILL NUMBER 9. Division of Decimals.

SAMPLES.

a) Divide 25.994 by .82.

$$\begin{array}{r}
 31.7 \text{ Answer.} \\
 .82 \overline{) 25.994} \\
 \underline{246} \\
 139 \\
 \underline{82} \\
 574 \\
 \underline{574} \\
 0000
 \end{array}$$

b) Divide 54.21 by .065.

$$\begin{array}{r}
 834. \text{ Answer.} \\
 .065 \overline{) 54.210} \\
 \underline{520} \\
 221 \\
 \underline{195} \\
 260 \\
 \underline{260} \\
 0000
 \end{array}$$

Explanation: Move the decimal point in the divisor to the right so as to change the divisor to a whole number, and move the decimal point in the dividend the same number of places to the right. Annex zeros when needed. Place the decimal point in the quotient directly over the new position of the decimal point in the dividend. Divide as in whole numbers.

Special Drill No. 9. Divide the following:

- | | | | |
|-----------------------------|------------------------------|-----------------------------|----------------------------|
| 1 $24 \overline{) 91.2}$ | 2 $71 \overline{) 58.93}$ | 3 $4.4 \overline{) 42.24}$ | 4 $2.7 \overline{) 1.566}$ |
| 5 $.38 \overline{) 5.852}$ | 6 $2.3 \overline{) .1702}$ | 7 $.42 \overline{) 1.1382}$ | 8 $8.2 \overline{) .7872}$ |
| 9 $.024 \overline{) 1.344}$ | 10 $.068 \overline{) 49.64}$ | | |

SPECIAL DRILL NUMBER 10. Rounding off in Division.

SAMPLES.

Find the quotients to the nearest tenth:

a) $823 \div 36$	$22.86 +$	b) $682.9 \div 47$	$14.52 +$
	$36 \overline{) 823.00}$		$47 \overline{) 682.90}$
	$\underline{72} $		$\underline{47} $
	$103 $		$\underline{212} $
Answer:	$\underline{72} $	Answer:	$\underline{14.5} $
22.9	$\underline{310} $		$\underline{249} $
	$\underline{288} $		$\underline{235} $
	$\underline{220} $		$\underline{140} $
	$\underline{216} $		$\underline{94} $

Explanation: Annex as many zeros as necessary, in order that the quotient may have 1 more decimal place than required. If the

extra place is 5 or more, increase the previous place in the quotient by 1; drop the extra place if it is less than 5.

Special Drill No. 10.

Find the quotients to the nearest tenth:

- | | | | |
|-------------------------|------------------------|-------------------------|-------------------------|
| 1 $63/\overline{84}$ | 2 $19/\overline{72}$ | 3 $34/\overline{425}$ | 4 $72/\overline{683}$ |
| 5 $47/\overline{16.7}$ | 6 $51/\overline{96.2}$ | 7 $6.8/\overline{35.2}$ | 8 $9.3/\overline{8.73}$ |
| 9 $.28/\overline{15.5}$ | 10 $.89/\overline{76}$ | | |

SPECIAL DRILL NUMBER 11. Multiples of 10.

SAMPLES.

Multiply:

- | | |
|------------------------------|---------------------------------|
| a) $78.4 \times 10 = 784$ | d) $65.2 \times 20 = 1304$ |
| b) $638 \times 100 = 63,800$ | e) $.54 \times 300 = 162$ |
| c) $8.72 \times 1000 = 8720$ | f) $43.9 \times 4000 = 175,600$ |

Explanation: When a multiplier is a multiple of 10, each zero of the multiplier moves the decimal point in the multiplicand one place to the right, as in a, b, and c, above. Thus, move the decimal point in the multiplicand as many places to the right as there are zeros in the multiplier, and multiply the result by the first number in the multiplier. $43.9 \times 4000 = 43900 \times 4 = 175,600$, etc.

Special Drill No. 11. Multiply the following mentally:

- | | |
|-----------------------|------------------------|
| 1. 2.6×10 | 7. 9.28×30 |
| 2. 43.7×100 | 8. 34.5×300 |
| 3. 6.82×1000 | 9. 87.6×3000 |
| 4. 94.5×20 | 10. 128×40 |
| 5. 623×200 | 11. 5.79×500 |
| 6. $.82 \times 2000$ | 12. 4.31×6000 |

SPECIAL DRILL NUMBER 12. Division by Multiples of 10.

SAMPLES.

Divide:

- | | |
|-----------------------------|----------------------------|
| a) $1520 \div 10 = 152$ | d) $854 \div 20 = 42.7$ |
| b) $853 \div 100 = 8.53$ | e) $6.36 \div 300 = .0212$ |
| c) $64.9 \div 1000 = .0649$ | f) $762 \div 4000 = .1905$ |

Explanation: Move the decimal point in the dividend as many places to the left as there are zeros in a divisor which is a multiple

of 10, and then divide the result by the first number in the divisor. Thus, $6.36 \div 300 = .0636 \div 3 = .0212$, (e), etc.

Special Drill No. 12. Divide the following mentally:

- | | |
|---------------------|---------------------|
| 1. $850 \div 10$ | 7. $5.7 \div 30$ |
| 2. $93.4 \div 100$ | 8. $632 \div 400$ |
| 3. $36.7 \div 1000$ | 9. $96 \div 4000$ |
| 4. $18.2 \div 20$ | 10. $83.5 \div 50$ |
| 5. $650 \div 200$ | 11. $72.5 \div 500$ |
| 6. $462 \div 2000$ | 12. $471 \div 5000$ |

TABLES OF WEIGHTS AND MEASURES

Linear Measure

12 inches	= 1 foot
3 feet	= 1 yard
5½ yards	= 1 rod
16½ feet	= 1 rod
320 rods	= 1 mile
5280 feet	= 1 mile

Square Measure

144 square inches	= 1 square foot
9 square feet	= 1 square yard
30¼ square yards	= 1 square rod
160 square rods	= 1 Acre
43560 square feet	= 1 Acre
640 Acres	= 1 square mile
1 mile square	= 1 section
36 sections	= 1 township

Cubic Measure

1728 cubic inches	= 1 cubic foot
27 cubic feet	= 1 cubic yard

Weight Measure

16 ounces	= 1 pound
100 pounds	= 1 hundredweight (cwt)
2000 pounds	= 1 ton
2240 pounds	= 1 long ton
20 cwt.	= 1 ton

Liquid Measure

4 gills	= 1 pint
2 pints	= 1 quart
4 quarts	= 1 gallon
31½ gallons	= 1 barrel

Dry Measure

2 pints	= 1 quart
8 quarts	= 1 peck
4 pecks	= 1 bushel

Volume Equivalents

1 bushel (stricken)	= 2150.42 cubic inches
1 bushel (heaped)	= 2747.71 cubic inches
1 gallon	= 231 cubic inches
1 cubic foot	= 7.5 gallons (approx.)
1 cord wood	= 128 cubic feet

Some Practical Relations

1 cubic foot of silage	= 40 pounds
1 cubic foot of water	= 62.5 pounds
1 cubic foot of ice	= 57 pounds
1 ton of soft coal	= 36 cubic feet
1 ton of hard coal	= 40 cubic feet
1 hand (measure of horses)	= 4 inches

FORMULAS**Perimeters.**

1. Triangle: $P = a + b + c$
2. Rectangle: $P = 2l + 2w$
3. Square: $P = 4s$

Areas.

4. Rectangle: $A = b h$
5. Triangle: $A = \frac{1}{2} b h$
6. Parallelogram: $A = b h$
7. Trapezoid: $A = \frac{1}{2} (b + c) h$
8. Square: $A = s^2$

Volumes.

9. Rectangular solid: $V = l w h$
10. Cube: $V = e^3$

Circles.

11. Circumference: $C = 2 \pi r$ or $C = \pi d$
12. Area: $A = \pi r^2$
13. Cylinder: $V = \pi r^2 h$
 $\pi = 3.14$ or $\pi = 2\frac{2}{7}$

Geometric Facts.

1. 1 complete revolution = 360°
2. A straight angle = 180°
3. A right angle = 90°
4. The sum of the three angles of any triangle = 180° .

Trigonometric Ratios.

1. Tangent of angle = opp. arm / adj. arm
2. Sine of angle = opp. arm / hyp.

Rule of the Right Triangle.

1. To find hypotenuse: $c^2 = a^2 + b^2$
2. To find one arm: $a^2 = c^2 - b^2$

Lumber Measure: Bd. Ft. = l w t / 12**Special Agricultural Rules.****Dairying:**

1. Butterfat: $F = D T$
2. Test %: $T = F / D$
3. Dairy Product: $D = F / T$

Feeding:

4. T.D.N. = $P + C + 2.25 F$
5. N.R. = $1 : T. C. / P$

Fertilizing:

6. Element: $E = F T$
7. Test %: $T = E / F$
8. Fertilizer: $F = E / T$

Mechanics and Power.

1. Levers: $E \times E_d = W \times W_d$
2. Pulleys:
 $D \times \text{R.P.M. of Driver} = D \times \text{R.P.M. of Driven Pulley}$
3. Gears: $T \times \text{R.P.M. of Driver} = T \times \text{R.P.M. of Driven Gear}$
4. Work = force $\times$ distance
5. 1 Horse Power = 33,000 foot pounds per minute

Interest.

1. Simple interest: $I = P R T$
2. Total Amount: $A = P + I$
3. Discount: $A = P - I$

TABLE OF WEIGHTS OF COMMODITIES.

Commodity	Unit	Approximate net weight	Commodity	Unit	Approximate net weight
		Pounds			Pounds
Alfalfa seed	Bushel	60	Orchard grass seed	Bushel	14
Apples, fresh	{ do.	48	Peaches, fresh	do.	48
Apricots	Bushel	48	Peanuts, unshelled:		
Western	Crate	22	Virginia type	Bushel	22
Barley	Bushel	48	Runners,		
Beans:			southeast-	do.	28
Lima, dry	do.	56	ern	do.	30
Other, dry	do.	60	Spanish	do.	50
Blackberries	24-quart crate	36	Pears	Box	46
Bluegrass seed	Bushel	14-30	Western		
Buckwheat	do.	48-52	Peas:		
Butter	Tub	63	Green, un-	Bushel	30
Cabbage	Western crate	85	shelled	do.	60
Cherries:			Dry	Crate	70
With stems	Bushel	56	Pineapples	Bushel	56
Without stems	do.	64	Plums and prunes	Crate	20
Clover seed	Bushel	60	Potatoes	Bushel	60
Corn:			Barrel		165
Ear, husked	do.	70	Bushel		48
Shelled	do.	56	Quinces	24-quart crate	36
Green, sweet	do.	35	Raspberries		
Meal	do.	50	Rice:		
Cotton	{ Bale, gross	500	Rough	Bushel	45
Cowpeas	Bale, net	478	Milled	Barrel	162
Cream, 30-percent	Bushel	60	Rye	Pocket	100
butterfat.	Gallon	8.43	Sorgo seed	Bushel	56
Eggs, average size	Case, 30 dozen	45	do.	do.	50
Flaxseed	Bushel	56	Soybeans	do.	60
Grain sorghums	do.	56 and 53	Soybean oil	Gallon	7.5
Grapefruit:			Strawberries	24-quart crate	36
Florida	Box	80	Sudan grass seed	Bushel	40
California	do.	60	Timothy seed	do.	45
Grapes	Bushel	48	Tobacco:		
Eastern	12-quart basket	18	Maryland	Hogshead	600-800
Western	4-basket crate	20	Virginia fire-	do.	1,050-1,350
Lemons,			cured		
California	Box	76	Kentucky and	do.	1,350-1,650
Lettuce	Western crate	75	Tennessee fire-	do.	250-365
Milk (specific			cured	Case	150-175
gravity 1.032).	Gallon	8.6	Cigar leaf	Bale	53
Millet	Bushel	48-50	Tomatoes	Bushel	60
Oats	do.	32	Velvetbeans	do.	60
Oranges:			(hulled)	do.	60
Florida	Box	90	Vetch	do.	50
California	Box	70	Walnuts	do.	60
			Wheat	do.	60

Taken from: Approximate or Average Weights of Various Commodities and Other Conversion Factors, Separate from Agricultural Statistics, 1938, United States Department of Agriculture.

The weights given in this table are approximate or average, and hence not all of them are recognized as legal weights in all of the States.

TABLE OF SQUARES AND SQUARE ROOTS

<i>No.</i>	<i>Square</i>	<i>Square Root</i>	<i>No.</i>	<i>Square</i>	<i>Square Root</i>
1	1	1.000	51	2,601	7.141
2	4	1.414	52	2,704	7.211
3	9	1.732	53	2,809	7.280
4	16	2.000	54	2,916	7.348
5	25	2.236	55	3,025	7.416
6	36	2.449	56	3,136	7.483
7	49	2.645	57	3,249	7.549
8	64	2.828	58	3,364	7.615
9	81	3.000	59	3,481	7.681
10	100	3.162	60	3,600	7.745
11	121	3.316	61	3,721	7.810
12	144	3.464	62	3,844	7.874
13	169	3.605	63	3,969	7.937
14	196	3.741	64	4,096	8.000
15	225	3.872	65	4,225	8.062
16	256	4.000	66	4,356	8.124
17	289	4.123	67	4,489	8.185
18	324	4.242	68	4,624	8.246
19	361	4.358	69	4,761	8.306
20	400	4.472	70	4,900	8.366
21	441	4.582	71	5,041	8.426
22	484	4.690	72	5,184	8.485
23	529	4.795	73	5,329	8.544
24	576	4.898	74	5,476	8.602
25	625	5.000	75	5,625	8.660
26	676	5.099	76	5,776	8.717
27	729	5.196	77	5,929	8.774
28	784	5.291	78	6,084	8.831
29	841	5.385	79	6,241	8.888
30	900	5.477	80	6,400	8.944
31	961	5.567	81	6,561	9.000
32	1,024	5.656	82	6,724	9.055
33	1,089	5.744	83	6,889	9.110
34	1,156	5.830	84	7,056	9.165
35	1,225	5.916	85	7,225	9.219
36	1,296	6.000	86	7,396	9.273
37	1,369	6.082	87	7,569	9.327
38	1,444	6.164	88	7,744	9.380
39	1,521	6.245	89	7,921	9.433
40	1,600	6.324	90	8,100	9.486
41	1,681	6.403	91	8,281	9.539
42	1,764	6.480	92	8,464	9.591
43	1,849	6.557	93	8,649	9.643
44	1,936	6.633	94	8,836	9.695
45	2,025	6.708	95	9,025	9.746
46	2,116	6.782	96	9,216	9.797
47	2,209	6.855	97	9,409	9.848
48	2,304	6.928	98	9,604	9.899
49	2,401	7.000	99	9,801	9.949
50	2,500	7.071	100	10,000	10.000

ORCHARD PLANTING

Number of Trees per Acre

<i>Distance apart</i>	<i>Square planting</i>	<i>Hexagonal planting</i>	<i>Quincunx planting</i>
16 x 16.....	170	196	303
18 x 18.....	134	154	239
20 x 20.....	108	125	129
22 x 22.....	90	104	148
24 x 24.....	75	87	132
25 x 25.....	69	80	125
26 x 26.....	64	74	114
28 x 28.....	56	64	100
30 x 30.....	48	55	85
32 x 32.....	43	49	76
33 x 33.....	40	46	71
35 x 35.....	35	41	65
40 x 40.....	27	31	48
45 x 45.....	22	25	39

Suggestions on Orchard Planting, by Roy E. Marshall, page 8.
Michigan Agricultural Station Regular Bulletin No. 262.

SUGGESTED DIMENSIONS FOR TRENCH SILOS

Number of cows	Width of trench at top	Width of trench at bottom	Depth of trench	Length of trench based on number days feeding period			
				75 da.	100 da.	125 da.	150 da.
	feet	feet	feet	feet	feet	feet	feet
6	6	4	5	18	24	30	35
8	6	4	5	24	32	40	48
10	6	4	5	30	40	50	60
12	7	5	6	25	34	42	50
14	7	5	6	29	39	49	59
16	8	6	6	28	38	48	58
18	8	6	7	28	37	46	56
20	9	7	7	27	36	45	54
24	10	7	7	31	41	51	61
28	12	8	7	30	40	50	60
32	12	8	8	30	40	50	60
36	12	8	8	34	45	57	68
40	12	8	8	38	50	63	75
44	13	9	8	38	50	63	75
48	14	10	8	38	50	63	75
52	14	10	8	41	53	68	82

The Trench Silo, by Grimes and Nichols. Alabama Agr. Exp. Sta. Cir. No. 59. Page 4.

This table is compiled on a basis of 35 pounds, or 1 cubic foot, of silage per day for each cow. A block of silage 3 or 4 inches thick, cut from top to bottom of the trench, should be removed from the entire face of the silo each day.

CAPACITY OF CYLINDRICAL SILOS

Capacity of silos with different diameters and depths of silage¹

Depth of silage (feet)	Capacity with an inside diameter of—										
	10 feet	11 feet	12 feet	13 feet	14 feet	15 feet	16 feet	17 feet	18 feet	19 feet	20 feet
	Tons	Tons	Tons	Tons	Tons	Tons	Tons	Tons	Tons	Tons	Tons
20	27										
22	30	37									
24	34	41	49								
26	38	46	55	65							
28	43	52	61	72	84						
30	47	57	68	80	92	106	121				
32	51	62	74	87	100	115	131	148			
34	56	67	80	94	109	125	142	161	180		
36		73	86	101	117	133	153	173	194	216	
38			93	109	126	145	165	186	209	233	258
40			100	117	135	155	177	200	224	249	276
42				124	144	165	188	212	237	264	293
44					152	174	198	224	251	279	310
46						184	209	236	265	295	327
48							220	248	279	310	344
50								261	293	326	361

¹ Capacities given are for normal corn silage when the silo is filled at the average speed of 20 to 50 tons per day with 1 man in the silo and refilled once after silage has settled.

Silos Types and Construction, by J. R. McCalmont. U. S. Dept. of Agr. Farmers' Bull. No. 1820, Page 5.

Relation of size of herd to diameter of silo for winter feeding, on the basis of 40 pounds of silage per cubic foot and the removal of 2 inches of silage daily to avoid spoilage

Inside diameter of silo (feet)	Volume per foot of depth	Amount to be removed—			Animals that may be fed with a daily allowance per head of—			
		Daily	For a feeding period of—					
				180 days	240 days	40 pounds	30 pounds	20 pounds
	Cubic feet	Pounds	Tons	Tons	Number	Number	Number	Number
10.....	78.5	524	47	63	13	17	26	35
11.....	95.0	634	57	76	16	21	31	42
12.....	113.1	754	68	90	19	25	37	50
13.....	132.7	885	80	106	22	29	44	59
14.....	153.9	1,027	92	123	25	34	51	68
15.....	176.7	1,178	106	141	29	39	59	78
16.....	201.0	1,340	120	161	33	44	67	89
17.....	227.0	1,513	136	182	38	50	75	101
18.....	254.5	1,696	153	203	42	56	85	113
20.....	314.2	2,094	188	251	52	70	104	139

Silos Types and Construction. U. S. Dept. of Agr. Farmers' Bull. No. 1820. Page 4.

Relation of size of herd to diameter of silo for summer feeding, on the basis of 40 pounds of silage per cubic foot and the removal of 3 inches of silage daily to avoid spoilage

Inside di- ameter of silo (feet)	Volume per foot of depth	Amount to be removed—					Animals that may be fed with a daily allowance per head of—			
		Daily	For a feeding period of—				30 pounds	20 pounds	15 pounds	10 pounds
			30 days	45 days	60 days					
	Cubic Feet	Pounds	Tons	Tons	Tons	Number	Number	Number	Number	
10.....	78.5	785	12	18	24	26	39	52	78	
11.....	95.0	950	14	21	28	31	47	63	95	
12.....	113.1	1,131	17	25	34	38	56	75	113	
13.....	132.7	1,327	20	30	40	44	66	88	132	
14.....	153.9	1,539	23	35	46	51	77	102	154	
15.....	176.7	1,767	27	40	54	59	88	118	177	
16.....	201.0	2,010	30	45	60	67	100	134	201	

Silos Types and Construction, by J. R. McCalmont. U. S. Dept. of Agr. Farmers' Bull. No. 1820. Page 5.

TABLES OF WEIGHTS AND MEASURES

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**VOLUME OF ROUND STACKS OF HAY OF
SPECIFIED DIMENSIONS**

[Volume figures given to the nearest 5]

	Indicated volume in cubic feet when the over is—												
Circumference (feet)	25 feet	26 feet	27 feet	28 feet	29 feet	30 feet	31 feet	32 feet	33 feet	34 feet	35 feet	36 feet	37 feet
45	825	960	1,090										
46	840	975	1,105	1,235									
47	855	990	1,120	1,250	1,385	1,505							
48	870	1,005	1,135	1,265	1,400	1,525	1,650	1,785					
49	885	1,020	1,150	1,285	1,420	1,540	1,670	1,805	1,935				
50	900	1,035	1,165	1,300	1,435	1,560	1,690	1,825	1,955	2,090	2,215		
51	915	1,050	1,180	1,315	1,450	1,580	1,710	1,845	1,980	2,110	2,240	2,370	2,495
52	930	1,065	1,200	1,330	1,465	1,600	1,730	1,865	2,000	2,130	2,265	2,400	2,530
53	945	1,080	1,215	1,345	1,485	1,615	1,750	1,880	2,020	2,155	2,290	2,430	2,560
54	960	1,095	1,230	1,360	1,500	1,630	1,770	1,900	2,040	2,180	2,320	2,460	2,595
55	975	1,110	1,245	1,380	1,515	1,650	1,790	1,920	2,065	2,205	2,345	2,490	2,630
56	990	1,125	1,260	1,395	1,530	1,665	1,810	1,940	2,085	2,230	2,375	2,520	2,660
57	1,005	1,140	1,275	1,410	1,550	1,685	1,830	1,960	2,105	2,250	2,400	2,545	2,695
58	1,020	1,155	1,290	1,435	1,565	1,705	1,850	1,980	2,125	2,275	2,425	2,575	2,725
59	1,035	1,170	1,310	1,450	1,580	1,720	1,865	2,000	2,150	2,300	2,455	2,605	2,755
60	1,050	1,185	1,325	1,465	1,600	1,740	1,885	2,020	2,170	2,325	2,480	2,635	2,790
61	1,065	1,200	1,340	1,485	1,615	1,760	1,905	2,040	2,195	2,345	2,510	2,665	2,825
62	1,080	1,215	1,355	1,500	1,635	1,775	1,925	2,060	2,215	2,365	2,535	2,695	2,855
63	1,095	1,230	1,370	1,515	1,655	1,795	1,945	2,080	2,235	2,390	2,565	2,725	2,890
64	1,110	1,245	1,385	1,530	1,670	1,810	1,960	2,100	2,260	2,415	2,585	2,755	2,920
65	1,125	1,260	1,400	1,545	1,685	1,830	1,980	2,120	2,280	2,440	2,615	2,780	2,950
66	1,140	1,275	1,420	1,560	1,705	1,850	2,000	2,140	2,300	2,465	2,640	2,810	2,985
67	1,155	1,290	1,435	1,575	1,720	1,865	2,020	2,160	2,325	2,485	2,665	2,840	3,015
68	1,170	1,305	1,450	1,595	1,740	1,885	2,040	2,180	2,345	2,510	2,690	2,870	3,050
69	1,185	1,320	1,465	1,610	1,755	1,905	2,055	2,200	2,365	2,530	2,715	2,900	3,085
70	1,200	1,335	1,480	1,625	1,770	1,925	2,075	2,220	2,385	2,555	2,745	2,930	3,115
71	1,215	1,350	1,495	1,640	1,790	1,940	2,095	2,240	2,405	2,580	2,770	2,960	3,145
72	1,230	1,365	1,515	1,660	1,805	1,960	2,115	2,260	2,430	2,605	2,795	2,990	3,175
73	1,245	1,380	1,530	1,675	1,820	1,975	2,135	2,280	2,450	2,625	2,825	3,015	3,210
74	1,260	1,395	1,545	1,690	1,840	1,995	2,150	2,300	2,470	2,650	2,850	3,045	3,245
75		1,410	1,560	1,705	1,855	2,010	2,170	2,326	2,495	2,675	2,875	3,075	3,275
76		1,425	1,575	1,725	1,870	2,030	2,190	2,344	2,515	2,695	2,905	3,105	3,310
77			1,590	1,740	1,890	2,050	2,210	2,366	2,540	2,720	2,930	3,135	3,340
78			1,605	1,755	1,905	2,070	2,230	2,388	2,560	2,745	2,955	3,165	3,375
79				1,775	1,925	2,090	2,250	2,400	2,580	2,765	2,980	3,195	3,405
80				1,790	1,945	2,105	2,270	2,420	2,605	2,790	3,010	3,225	3,440
81				1,805	1,960	2,125	2,285	2,440	2,625	2,815	3,035	3,255	3,475
82				1,820	1,975	2,145	2,305	2,460	2,645	2,835	3,060	3,280	3,500
83					1,995	2,160	2,325	2,480	2,665	2,860	3,090	3,310	3,535
84						2,180	2,345	2,500	2,690	2,880	3,115	3,340	3,570
85								2,520	2,710	2,905	3,140	3,370	3,600
86									2,735	2,930	3,170	3,400	3,635
87											3,195	3,430	3,665
88												3,460	3,700
89												3,490	3,730
90													3,765
91													
92													
93													
94													
95													
96													
97													
98													

Volume of round stacks of hay of specified dimensions—Continued

[Volume figures given to the nearest 5]

Circumference (feet)	Indicated volume in cubic feet when the over is—													
	38 feet	39 feet	40 feet	41 feet	42 feet	43 feet	44 feet	45 feet	46 feet	47 feet	48 feet	49 feet	50 feet	
45														
46														
47														
48														
49														
50														
51														
52	2,665	2,795												
53	2,700	2,835	2,975											
54	2,735	2,875	3,015	3,160										
55	2,770	2,915	3,060	3,210	3,360	3,505								
56	2,805	2,955	3,105	3,255	3,415	3,565	3,720							
57	2,845	2,995	3,150	3,305	3,465	3,625	3,785	3,940						
58	2,880	3,035	3,195	3,350	3,515	3,680	3,850	4,010	4,175					
59	2,915	3,075	3,235	3,400	3,570	3,740	3,915	4,080	4,245	4,415				
60	2,950	3,115	3,280	3,445	3,625	3,795	3,975	4,150	4,320	4,490	4,670			
61	2,985	3,155	3,325	3,495	3,675	3,855	4,040	4,215	4,390	4,570	4,750	4,925		
62	3,020	3,195	3,365	3,540	3,730	3,915	4,105	4,285	4,465	4,650	4,830	5,015	5,200	
63	3,055	3,235	3,410	3,585	3,780	3,970	4,165	4,355	4,540	4,730	4,910	5,105	5,295	
64	3,090	3,275	3,455	3,635	3,835	4,030	4,230	4,425	4,615	4,805	4,995	5,195	5,390	
65	3,125	3,315	3,495	3,680	3,885	4,085	4,290	4,490	4,690	4,885	5,075	5,285	5,485	
66	3,160	3,355	3,540	3,730	3,935	4,145	4,355	4,560	4,760	4,960	5,160	5,370	5,580	
67	3,195	3,395	3,585	3,780	3,990	4,205	4,420	4,630	4,830	5,040	5,245	5,460	5,670	
68	3,230	3,430	3,630	3,825	4,045	4,265	4,485	4,695	4,900	5,120	5,330	5,550	5,765	
69	3,265	3,470	3,670	3,875	4,095	4,320	4,545	4,760	4,970	5,195	5,415	5,640	5,860	
70	3,300	3,510	3,715	3,920	4,150	4,375	4,610	4,825	5,045	5,275	5,495	5,730	5,955	
71	3,335	3,550	3,760	3,970	4,205	4,435	4,670	4,895	5,120	5,355	5,580	5,820	6,050	
72	3,375	3,590	3,805	4,015	4,255	4,495	4,735	4,965	5,195	5,435	5,665	5,910	6,145	
73	3,410	3,630	3,845	4,065	4,310	4,550	4,795	5,030	5,270	5,515	5,750	6,000	6,240	
74	3,445	3,665	3,890	4,110	4,360	4,610	4,855	5,095	5,340	5,595	5,835	6,090	6,335	
75	3,480	3,705	3,935	4,160	4,415	4,670	4,915	5,165	5,415	5,675	5,915	6,180	6,430	
76	3,515	3,745	3,975	4,205	4,465	4,725	4,980	5,235	5,490	5,750	6,000	6,270	6,525	
77	3,550	3,785	4,020	4,250	4,520	4,785	5,045	5,305	5,560	5,830	6,085	6,355	6,620	
78	3,585	3,825	4,065	4,300	4,570	4,840	5,105	5,370	5,635	5,910	6,170	6,445	6,715	
79	3,620	3,865	4,105	4,345	4,625	4,895	5,170	5,440	5,710	5,990	6,255	6,535	6,810	
80	3,655	3,905	4,150	4,395	4,675	4,955	5,235	5,510	5,785	6,070	6,340	6,625	6,905	
81	3,690	3,945	4,195	4,440	4,730	5,010	5,295	5,575	5,855	6,145	6,425	6,715	7,000	
82	3,725	3,985	4,240	4,490	4,785	5,070	5,360	5,645	5,930	6,225	6,510	6,800	7,090	
83	3,760	4,025	4,280	4,535	4,830	5,130	5,425	5,715	6,005	6,305	6,595	6,890	7,185	
84	3,795	4,065	4,325	4,580	4,885	5,190	5,485	5,785	6,080	6,385	6,675	6,980	7,280	
85	3,830	4,105	4,365	4,630	4,935	5,245	5,550	5,850	6,155	6,465	6,760	7,070	7,375	
86	3,865	4,145	4,410	4,675	4,990	5,300	5,615	5,920	6,230	6,545	6,845	7,160	7,470	
87	3,900	4,185	4,455	4,725	5,040	5,360	5,680	5,990	6,300	6,620	6,930	7,250	7,565	
88	3,940	4,220	4,500	4,770	5,090	5,420	5,745	6,060	6,375	6,700	7,015	7,340	7,660	
89	3,975	4,260	4,540	4,815	5,145	5,475	5,805	6,125	6,450	6,780	7,100	7,430	7,755	
90	4,010	4,300	4,585	4,860	5,200	5,535	5,865	6,195	6,525	6,860	7,185	7,520	7,845	
91	4,045	4,340	4,630	4,910	5,250	5,595	5,930	6,265	6,600	6,940	7,270	7,605	7,940	
92	4,080	4,380	4,670	4,955	5,305	5,650	5,995	6,335	6,675	7,020	7,355	7,695	8,035	
93		4,420	4,715	5,005	5,360	5,710	6,055	6,400	6,750	7,095	7,440	7,785	8,130	
94		4,460	4,760	5,050	5,410	5,765	6,120	6,470	6,825	7,175	7,525	7,875	8,225	
95			4,805	5,100	5,465	5,825	6,180	6,540	6,895	7,255	7,610	7,965	8,320	
96				5,150	5,515	5,885	6,245	6,610	6,970	7,335	7,695	8,055	8,415	
97					5,195	5,570	5,945	6,310	6,680	7,045	7,415	7,780	8,145	
98						5,625	6,000	6,370	6,750	7,120	7,495	7,865	8,235	
													8,605	

Measuring Hay in Stacks, by W. H. Hosterman. U. S. Dept. of Agr. Leaflet No. 72. Pages 5, 6.

FORESTRY

International log rule

[The contents of logs in board feet, by using a circular saw, cutting one-fourth inch kerf, and sawing carefully by good methods]

Diameter of log at small end and inside bark (inches)	Length of log in feet--													
	8	9	10	11	12	13	14	15	16	17	18	19	20	
4.....	2	2	3	3	4	5	5	5	6	7	7	8	9	
5.....	4	5	6	7	7	8	9	11	12	13	15	16	17	
6.....	7	9	10	11	13	14	16	18	19	21	23	25	27	
7.....	12	14	15	17	19	21	24	26	28	31	34	36	39	
8.....	16	19	21	24	27	30	33	36	39	42	46	49	52	
9.....	23	26	29	33	36	40	43	47	51	55	59	63	68	
10.....	29	33	37	42	45	51	54	59	64	69	75	82	89	
11.....	36	42	46	52	57	63	68	74	80	86	95	100	107	
12.....	44	51	57	62	70	77	83	91	97	103	111	119	129	
13.....	52	60	68	76	83	92	100	108	116	124	134	143	151	
14.....	62	71	80	98	107	107	117	127	136	147	158	168	176	
15.....	73	82	94	104	114	125	136	146	157	170	181	195	204	
16.....	84	96	108	119	131	144	156	167	181	194	207	222	233	
17.....	96	110	123	136	149	163	177	192	205	221	235	251	265	
18.....	110	124	139	155	169	185	201	218	232	250	267	282	300	
19.....	123	140	156	175	190	210	225	244	261	280	299	317	337	
20.....	138	157	174	197	212	232	251	270	290	310	330	352	374	
21.....	152	172	193	215	234	256	279	299	321	344	366	389	412	
22.....	168	192	214	238	259	282	307	330	354	379	404	429	453	
23.....	186	212	235	260	285	310	337	362	388	415	445	470	498	
24.....	203	232	257	285	311	339	367	398	424	452	484	514	543	
25.....	223	253	281	311	339	370	400	433	462	494	526	560	590	
26.....	241	273	304	337	368	402	435	468	502	537	570	606	640	
27.....	262	296	329	364	400	434	471	504	543	580	617	657	692	
28.....	281	319	356	395	432	470	509	545	586	623	664	706	748	
29.....	303	344	383	425	463	505	546	587	630	670	712	756	801	
30.....	326	369	411	455	498	542	586	628	674	719	765	810	858	
31.....	348	397	442	488	532	582	628	670	724	771	819	868	918	
32.....	373	424	471	520	570	621	672	718	773	821	874	927	979	
33.....	397	452	503	557	608	662	715	766	822	877	929	988	1,042	
34.....	423	481	534	592	647	702	760	818	876	932	990	1,052	1,109	
35.....	450	509	567	627	685	747	805	872	930	992	1,050	1,117	1,176	
36.....	477	540	599	662	727	790	853	920	984	1,052	1,114	1,184	1,244	
37.....	503	570	635	702	767	835	906	974	1,042	1,109	1,178	1,251	1,317	
38.....	532	603	672	742	811	880	954	1,028	1,098	1,174	1,245	1,320	1,388	
39.....	561	635	710	783	858	932	1,004	1,082	1,158	1,237	1,312	1,389	1,467	
40.....	594	671	749	823	902	983	1,059	1,139	1,216	1,300	1,381	1,462	1,543	

Measuring and Marketing Farm Timber, by Mattoon and Barrows. U. S. Dept. of Agr. Farmers' Bull. No. 1210. Page 17.

Amount of saw timber in hardwood trees of different diameters and merchantable heights

[Stump height, 2 feet. Trees over 75 years old. Scribner decimal C rule.]

Diameter of tree, breast-high (inches)	Number of 16-foot logs									Diam- eter of top (inside bark)	Basis
	1	1½	2	2½	3	3½	4	4½	5		
	Volume—board feet										
9	20	27	35	43						Inches	Trees
8	20	32	42	53						6	1
10	20	36	52	64	81					3	2
11	21	43	62	78	98					6	4
12	23	50	73	93	120	140	180			6	3
13	25	58	86	110	140	170	200			7	4
14	27	67	100	130	160	190	230	260		7	9
15	30	77	120	150	180	220	260	300		8	15
16	34	89	130	170	200	250	290	340	390	8	18
17	38	100	150	190	230	280	320	380	440	9	40
18	43	120	170	210	260	310	360	420	490	9	56
19	48	130	200	240	290	350	400	470	540	10	65
20	54	150	220	270	330	390	450	520	590	10	75
21	62	170	250	300	370	440	500	580	650	11	86
22	69	190	270	340	410	480	550	640	720	11	90
23	77	210	300	380	450	530	610	700	790	12	67
24	85	230	340	420	500	580	670	770	860	12	80
25	93	250	370	460	550	640	740	840	940	13	56
26	100	280	410	510	600	700	810	910	1,020	13	89
27	110	300	450	560	660	770	880	990	1,110	14	68
28	120	330	490	610	720	830	960	1,030	1,200	14	81
29	130	360	530	660	780	900	1,030	1,160	1,300	15	61
30	140	390	580	720	850	980	1,120	1,250	1,400	15	47
31		420	630	770	910	1,050	1,200	1,350	1,510	16	45
32		450	690	830	980	1,130	1,290	1,450	1,620	16	40
33		480	740	890	1,050	1,211	1,380	1,560	1,730	17	49
34			800	950	1,120	1,290	1,480	1,670	1,860	17	30
35			860	1,010	1,180	1,380	1,570	1,790	1,990	18	22
36			920	1,070	1,250	1,460	1,680	1,910	2,140	18	17
37				1,130	1,320	1,550	1,780	2,040	2,290	19	24
38				1,190	1,390	1,640	1,890	2,170	2,450	19	11
39				1,250	1,460	1,730	2,000	2,300	2,600	20	16
40				1,310	1,540	1,820	2,120	2,430	2,760	20	15
41					1,610	1,910	2,240	2,570	2,930	21	6
42					1,680	2,000	2,360	2,720	3,100	21	3
43					1,750	2,090	2,470	2,860	3,270	22	3
44					1,830	2,180	2,590	3,010	3,450	22	2
											1,300

¹ Gives volumes of trees about as sawed out in average practice.

Correction factors for different species

Chestnut, for diameters from 8 to 40 inches, subtract 10 per cent.

Chestnut oak, for diameters from 32 to 40 inches, add 10 per cent.

White oak, for diameters from 18 to 40 inches, add 10 per cent.

Other common hardwoods, for all diameters, use the table without change.

Measuring and Marketing Farm Timber, by Mattoon and Barrows. U. S. Dept. of Agr. Farmers' Bull. No. 1210. Page 28.

Amount of saw timber in softwood trees (pines, spruces, etc.) of different diameters and merchantable heights

[Stump height, 2 feet. Diameter (inside bark) of top, 6 inches. Trees over 75 years old. Scribner decimal C rule.]

Diameter of tree, breast-high (inches)	Number of 16-foot logs						Basis (trees)	
	2	2½	3	3½	4	4½		5
	Volume (board feet)							
8	37	52	66	75	84	.....	.....	12
9	41	58	70	82	93	.....	.....	9
10	47	66	77	92	100	120	.....	12
11	53	74	86	100	120	140	.....	13
12	60	83	97	120	140	160	200	8
13	68	94	110	130	160	190	220	4
14	77	110	120	150	180	210	240	7
15		120	140	170	200	240	270	11
16		130	160	190	230	270	310	20
17		150	180	220	260	300	340	21
18		170	210	250	280	330	380	20
19		190	230	280	320	370	420	34
20		210	260	310	360	410	470	27
21			290	350	400	460	520	33
22			320	390	440	510	570	40
23			360	430	490	560	620	37
24			400	470	540	620	680	37
25			440	520	600	680	740	47
26			480	560	660	740	810	52
27				600	720	800	880	43
28				650	780	870	950	45
29					840	940	1,030	39
30					910	1,010	1,100	47
31						1,080	1,180	40
32						1,150	1,260	44
33						1,230	1,340	39
34							1,420	36
35							1,500	34
36							1,580	29
								840

* Gives volumes of trees about as sawed out in average practice.

Correction factors for different species

Hemlock:

- For diameters from 8 to 10 inches, add 10 per cent.
- For diameters from 11 to 20 inches, add 22 per cent.
- For diameters from 21 inches and up, add 20 per cent.

Red spruce:

- For diameters from 8 to 10 inches, add 5 per cent.
- For diameters from 11 inches and up, add 25 per cent.

Shortleaf pine:

- For diameters from 10 inches and under, add 15 per cent.
- For diameters from 11 to 19 inches, add 25 per cent.
- For diameters from 20 to 23 inches, add 35 per cent.
- For diameters from 24 inches and over, add 40 per cent.

White pine and other common conifers, for all diameters, use the table without change.

Measuring and Marketing Farm Timber, by Mattoon and Barrows. U. S. Dept. of Agr. Farmers' Bull. 1210. Page 29.

Average taper for trees yielding four 16-foot logs

From diameter breast-high to top of first log.....2 to 2½ inches

From top of first to top of second log.....1½ to 2½ inches

From top of second to top of third log.....2 to 3 inches

From top of third to top of fourth log.....3½ to 4 inches

Above averages are from measurements of white pines. Each specie of tree has its own characteristic form and taper. Most trees grown in the forest where they attain good form will taper 2 to 4 inches for every 16 feet in height.

Estimating Timber in the Farm Woodlot, by J. Bentley, Jr. Cornell Extension Bull. No. 232. Page 17.

Amount in inches that must be deducted from top diameter of logs outside bark, in order to obtain diameters inside bark

<i>Size of 16-foot logs</i>	<i>Trees with thick bark (A)</i>	<i>Trees with thin bark (B)</i>
On logs 24 inches and over....	Deduct 3 inches.....	Deduct 1 to 2 inches
On logs 12 to 24 inches.....	Deduct 2 inches.....	Deduct 1 inch
On logs 6 to 12 inches	Deduct 1 inch	Deduct 1 inch *

(A) Trees with thick bark: oaks (especially chestnut oak and black oak), pitch pine, chestnut, walnut, butternut, ash, tulip poplar, cottonwood, locust, and hemlock.

(B) Trees with thin or medium bark: white pine, spruce, balsam fir, beech, hard maple, soft maple, birches, hickories, sycamore, cherry, basswood (except in old trees).

* Fractions of inches are not considered in scaling, and it is therefore useless to make smaller deductions.

Estimating Timber in the Farm Woodlot. Cornell Extension Bull. No. 232. Page 17.

AVERAGE PER CENTS OF DRY MATTER AND OF DIGESTIBLE NUTRIENTS IN SOME AMERICAN FEEDING STUFFS

Note: The following numbers may also be used as the number of pounds in
100 pounds of feed.

Feeding Stuff	Dry Matter	Dig. Nutrients		
		Protein	Carbo- hydrates	Fat
<i>Roughages</i>				
Alfalfa hay	90.4	10.6	38.3	0.6
Cabbage	9.4	1.9	5.7	0.2
Clover hay, red	88.2	7.0	41.6	1.5
Corn silage, dent, well matured	28.3	1.3	15.9	0.7
Corn stover (ears removed), very dry	90.6	2.2	47.7	1.0
Cottonseed hulls	90.6	0.1	42.1	0.7
Cowpea hay	90.4	12.6	34.6	1.0
Grass hay, mixed	89.0	3.5	45.5	1.2
Millet hay, common	90.0	5.2	42.2	1.8
Oat straw	89.6	0.9	41.5	0.8
Pasture grasses and clover, mixed	28.7	4.4	14.9	0.6
Sorghum fodder, sweet and dry	89.2	3.6	45.6	1.6
Soybean hay	90.8	11.1	35.1	2.0
Sunflower silage	22.2	1.1	9.9	0.7
Sweet corn silage	24.2	1.5	12.8	0.6
Timothy hay	88.7	2.9	41.5	1.2
Wheat straw	90.1	0.8	33.2	0.8
<i>Concentrates</i>				
Barley, common	90.4	9.3	65.7	1.6
Buckwheat, common	99.4	8.9	51.5	1.8
Corn, dent	88.5	7.4	68.2	3.6
Corn Bran	90.1	5.7	57.8	4.9
Corn Gluten Feed	90.5	22.7	50.5	1.9
Cottonseed meal, 43% grade	93.5	35.0	24.8	7.0
Cottonseed meal, 41% grade	92.8	33.9	24.5	6.7
Cowpeas	88.6	19.4	54.6	1.1
Distiller's corn grains, dried	93.6	22.3	39.6	10.3
Linseed meal (old process)	91.3	30.6	34.5	5.8
Oats	91.1	9.4	52.7	4.1
Peanut oil meal (old process)	93.4	38.0	26.0	8.1
Rye grain	90.4	10.3	67.3	1.1
Skimmilk, centrifugal	9.6	3.5	4.9	0.1
Soybean oil meal	91.7	37.7	33.5	4.9
Wheat	89.8	11.3	69.2	1.4
Wheat bran	90.6	13.1	47.9	4.1
Wheat standard middlings	90.0	14.4	53.5	4.7

Compiled from data taken by special permission of the Morrison Publishing Company, Ithaca, New York, from Feeds and Feeding, 20th Edition, by F. B. Morrison.

**TABLE SHOWING THE WEIGHT OF CREAM OF
DIFFERENT PERCENTAGES OF MILKFAT**

<i>Percentage of milkfat</i>	<i>Weight of one quart of cream in pounds</i>	<i>Weight of one gallon of cream in pounds</i>
20.....	2.115	8.460
25.....	2.100	8.400
30.....	2.088	8.352
40.....	2.055	8.220
50.....	2.028	8.112

Practical Examples in Dairy Arithmetic, by Ross and Guthrie. Cornell Extension Bulletin No. 129. Page 3.

FEEDING DAIRY CATTLE

Percentage of protein needed with various roughages to give the proper protein content to the grain mixture

<i>Kind of roughage</i>	<i>Low- protein feeds</i>	<i>Medium- protein feeds</i>	<i>High- protein feeds</i>	<i>Very high- protein feeds</i>
	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>
Non-legume hay and corn silage	40 45	15 10	25 20	20 25
Mixed hay containing 30 per cent legumes and corn silage	50 60	15 5	25 25	10 10
Clover hay and corn silage	60 65	15 10	15 20	10 5
Alfalfa or soybean hay and corn silage ..	70 80	25 15	5 —	— 5

Feeding the Dairy Cattle Efficiently, by Crandall and Turk, Cornell Extension Bulletin No. 363. Page 41.

FEEDING HORSES

Classification, composition, and net energy values per 100 pounds
of feeding stuffs for ruminants

Kind of feed	Class	Composition		Net energy value
		Dry matter	Digestible true protein	
DRIED ROUGHAGE				
<i>Hay and fodder from cereals</i>				
Brome grass, smooth	Carbohydrate	Pounds 91.5	Pounds 3.5	Therms 40.83
Corn (maize) fodder (ears included, medium dry)	do	81.7	2.3	43.94
Corn (maize) stover (ears removed, medium dry)	do	81.0	1.6	31.62
Kafir fodder, high in water	do	71.7	1.8	34.28
Kafir stover, high in water	do	72.7	1.0	27.65
Millet, Hungarian	do	85.7	3.9	46.96
Timothy and clover mixed	do	87.8	3.6	40.85
Oat hay	Carbohydrate	88.0	3.9	32.25
Orchard grass	do	88.4	3.3	44.93
Prairie hay	do	93.5	2.9	40.42
Red top	do	90.2	3.9	51.22
Sorghum fodder, computed to 80 per cent dry matter	do	80.0	1.5	32.30
Timothy, all analyses	do	88.4	2.2	43.02
<i>Hay and Fodder from legumes</i>				
Alfalfa, all analyses	Protein	91.4	7.1	34.23
Clover, alsike	do	87.7	5.3	34.42
Clover, crimson	do	89.4	6.9	36.21
Clover, red, all analyses	do	87.1	4.9	38.68
Clover, sweet white	do	91.4	6.7	39.98
Cowpeas, all analyses	do	90.3	9.2	37.59
Soy beans	do	91.4	8.8	44.03
<i>Straws</i>				
Barley	Carbohydrate	85.8	.6	36.61
Buckwheat	do	90.1	3.2	4.35
Oat	do	88.5	.8	34.81
Rice	do	92.5	.4	23.63
Rye	do	92.9	.5	17.59
Wheat	do	91.6	.3	7.22
FRESH GREEN ROUGHAGE				
<i>Green cereals, etc.</i>				
Barley fodder		23.2	2.0	14.08
Bluegrass, Kentucky, before heading		23.8	2.3	14.82
Bluegrass, Kentucky, headed out		36.4	2.2	17.77
Bluegrass, Kentucky, after bloom		43.6	1.6	21.01
Buckwheat, Japanese		36.6	1.5	17.78
Cabbage		8.9	1.3	8.87
Corn (maize) fodder, dent, all analyses		23.1	.8	14.60
Corn (maize) fodder, flint, all analyses		20.7	.8	13.53
Corn (maize) fodder, sweet, roasting ears or later		20.3	.9	13.38
Corn (maize) fodder, sweet, ears removed		21.5	.8	14.26
Millet, Hungarian		27.6	1.1	17.24

(Continued to next page.)

Classification, composition, and net energy values per 100 pounds of feeding stuffs for ruminants—Continued

Kind of feed	Class	Composition		Net energy value
		Dry matter	Digestible true protein	
		Pounds	Pounds	Therms
Oat fodder		26.1	2.0	14.06
Orchard grass		29.2	1.1	15.81
Rape		16.7	1.7	13.07
Rye fodder		21.3	1.4	15.99
Sorgo fodder		24.9	.4	15.37
Timothy, before bloom		24.2	1.1	18.36
Timothy, in bloom		32.1	.8	18.89
Timothy, in seed		46.4	1.0	26.36
Wheat fodder		27.4	1.9	18.75
SILAGE				
Corn (maize), well-matured, recent analysis		26.3	.6	15.90
Corn (maize), immature		21.0	.4	11.96
Corn (maize), from field-cured stover		19.6	.3	8.98
Clover		27.8	.8	7.26
Cowpeas		22.0	1.1	11.03
Soy beans		27.1	1.5	11.59
Sugar-beet pulp		10.0	.5	9.32
GRAINS				
Cereal grains				
Barley	Protein	90.7	8.3	89.94
Buckwheat	do	87.9	7.2	59.73
Corn (maize), dent	Carbohydrate	89.5	7.0	85.50
Corn (maize), flint	do	87.8	7.2	84.00
Corn (maize) and cob meal	do	89.6	5.7	75.80
Corn (maize) meal	do	88.7	6.4	85.20
Oats	Protein	90.8	8.7	67.56
Oatmeal	do	92.1	11.5	86.20
Rice, rough	Carbohydrate	90.4	4.5	77.33
Rye	Protein	90.6	9.0	93.71
Sorghum grain	Carbohydrate	87.3	6.7	89.75
Wheat, winter	Protein	89.1	7.7	91.66
Wheat, spring	do	89.9	8.1	91.41
Milling				
Buckwheat bran	Protein	88.8	9.1	30.59
Buckwheat hulls	Carbohydrate	89.7		-7.69
Buckwheat middlings	Protein	88.0	20.8	72.19
Hominy feed	Carbohydrate	89.9	6.5	88.78
Red-dog flour	Protein	88.9	13.2	78.80
Rice bran, high-grade	Carbohydrate	89.9	7.0	45.29
Rice meal	do	90.5	6.4	65.24
Rice polish	do	90.0	7.1	77.70
Rye bran	Protein	88.6	10.5	79.35
Wheat bran	do	89.9	10.8	53.00
Wheat middlings, flour	do	89.3	14.0	75.02
Wheat middlings, standard	do	89.6	12.0	59.10
OIL EXTRACTION				
Cottonseed meal, choice	Protein	92.5	35.4	93.46
Cottonseed meal, prime	do	92.2	32.0	90.00

Taken from: Feeding Horses, by Bell and Williams. The U. S. Dept. of Agr. Farmers' Bull. No. 1030. Pages 4, 5, 6.

AVERAGE PER CENTS OF FERTILIZING CONSTITUENTS IN SOME AMERICAN FEEDING STUFFS

<i>Feeding Stuff</i>	<i>Nitro- gen (N)</i>	<i>Phos- phorus (P)</i>	<i>Potas- sium (K)</i>	<i>Cal- cium (Ca)</i>
	<i>%</i>	<i>%</i>	<i>%</i>	<i>%</i>
Alfalfa hay	2.35	0.21	2.02	1.43
Barley grain	1.89	0.38	0.52	0.05
Barley straw	0.59	0.09	1.26	0.32
Buckwheat grain	1.90	0.29	0.27	0.04
Buckwheat straw	0.83	0.06	0.94	....
Clover hay, red	1.89	0.18	1.58	1.21
Corn, dent	1.55	0.28	0.33	0.01
Corn cobs	0.37	0.02	0.37	....
Corn stover	0.94	0.09	1.67	0.46
Corn silage	0.37	0.06	0.30	0.07
Cowpeas	3.78	0.47	1.45	0.10
Cowpea hay	2.98	0.25	1.45	1.13
Oats	1.92	0.33	0.40	0.09
Oat straw	0.64	0.13	1.66	0.36
Potatoes, tubers	0.35	0.05	0.45	0.01
Rye grain	1.97	0.37	0.54	0.04
Rye straw	0.48	0.11	0.86	0.28
Soybeans	5.90	0.60	1.91	0.20
Soybean hay	2.37	0.25	0.82	0.96
Sugar cane	0.14	0.04	0.37	....
Sunflowers	0.22	....	....	....
Timothy hay	0.99	0.16	1.36	0.27
Turnips	0.22	0.04	0.37	0.06
Velvet beans	0.56	0.06	0.37	....
Vetch, common	0.61	0.09	0.44	0.35
Wheat	2.10	0.43	0.44	0.03
Wheat straw	0.61	0.07	0.80	0.22

Taken by special permission of the Morrison Publishing Company, Ithaca, New York, from *Feeds and Feeding*, 20th Edition, by F. B. Morrison.

QUANTITIES OF PLANT FOOD ELEMENTS CONTAINED IN FARM PRODUCTS

<i>Crop</i>	<i>Amount</i>	<i>Pounds</i>		
		<i>Nitrogen</i>	<i>Phosphorus</i>	<i>Potassium</i>
		<i>N</i>	<i>P</i>	<i>K</i>
Sugar beets (Tops removed)	10 tons	36.6	5.9	46.7
Wheat	Grain 25 bu.	30.0	5.6	5.0
	Straw 2,500 lbs.	12.5	1.7	12.5
Total		42.5	7.3	17.5
Corn	Grain 50 bu.	46.4	7.9	9.2
	Stover 3,000 lbs.	30.0	3.9	34.9
	Cobs 500 lbs.	2.0	0.2	1.8
Total		78.4	12.0	45.9
Oats	Grain 50 bu.	32.0	5.7	8.0
	Straw 2,500 lbs.	16.0	2.2	25.9
Total		48.0	7.9	33.9
Rye	Grain 20 bu.	19.1	4.3	5.6
	Straw 2,000 lbs.	10.0	2.6	14.1
Total		29.1	6.9	19.7
Buckwheat	Grain 20 bu.	15.0	2.6	2.5
	Straw 5,000 lbs.	62.5	3.3	47.7
Total		77.5	5.9	50.2
Barley	Grain 35 bu.	29.4	5.5	7.0
	Straw 1,600 lbs.	13.4	2.0	20.4
Total		42.8	7.5	27.4
Beans	Seed 25 bu.	60.0	7.9	16.2
	Straw 2,000 lbs.	28.0	2.6	31.6
Total		88.0	10.5	47.8
Soybeans	Grain 15 bu.	79.5	11.8	24.9
	Straw 3,000 lbs.	19.2	1.7	15.4
Total		98.7	13.5	40.3
Beets, common, roots only	25,000 lbs.	62.5	10.9	103.9
Beets, mangles, roots only	40,000 lbs.	60.0	17.5	116.1
Turnips, common	20,000 lbs.	50.0	8.7	74.7
Rutabagas	20,000 lbs.	40.0	10.5	83.0
Potatoes	150 bu.	31.5	5.9	37.4
Carrots	10,000 lbs.	23.0	5.7	44.0
Parsnips	12,000 lbs.	26.4	10.5	64.8
Sweet clover—May 1	1,995 lbs.	75.0	5.9	41.2
	tops air dry.			
Alfalfa hay	3 tons	147.0	13.1	104.8
Timothy hay	2 tons	50.0	9.6	33.2
Clover hay	2 tons	84.0	8.7	66.4
Soybean hay	2 tons	92.0	12.2	36.6

Compiled from: Fertilizers, by Millar and Turk. Michigan Agr. Exp. Sta. Special Bull. No. 132. Pages 11, 12.

LIMING SOILS**Suitable pH Ranges for Various Field and Garden Crops****FIELD CROPS**

Alfalfa	6.5 to 7.5	Millet	5.5 to 7.0
Alsike clover	6.0 to 7.0	Red clover	6.0 to 7.0
Barley	5.5 to 7.0	Rye	5.5 to 7.0
Buckwheat	5.0 to 6.5	Sorghum	5.5 to 7.0
Corn	5.5 to 7.0	Soybeans	5.5 to 7.0
Cotton	5.0 to 6.0	Sweet clover	6.5 to 7.5
Cowpeas	5.5 to 7.0	Tobacco	5.0 to 5.6
Crimson clover	5.5 to 7.0	Velvet beans	5.5 to 6.5
Grasses	5.5 to 7.0	Vetch	5.5 to 6.5
Lespedeza	5.5 to 7.0	Wheat	5.5 to 7.0
Oats	5.5 to 7.0	White clover	6.0 to 7.0
Peanuts	5.5 to 6.5		

GARDEN CROPS

Asparagus	6.0 to 6.5	Onions	6.0 to 6.5
Beans (large lima)	5.5 to 6.5	Parsnips	5.5 to 6.5
Beans (small lima)	6.0 to 6.5	Peas	6.0 to 6.5
Beans (snap)	5.5 to 6.5	Peppers	5.5 to 6.5
Beets	6.0 to 6.5	Potatoes (Irish)	5.0 to 5.4
Cabbage	5.5 to 6.5	Potatoes (sweet)	5.0 to 5.5
Cantaloupe	6.0 to 6.5	Pumpkins	5.5 to 6.5
Carrot	5.5 to 6.5	Radish	5.2 to 6.5
Cauliflower	6.0 to 6.5	Rhubarb	5.0 to 6.5
Celery	6.0 to 6.5	Salsify	6.0 to 6.5
Corn (sweet)	5.2 to 6.5	Spinach	6.0 to 6.5
Cucumber	5.5 to 6.5	Squash	5.5 to 6.5
Eggplant	5.5 to 6.5	Strawberries	5.0 to 6.5
Kale	5.5 to 6.5	Tomatoes	5.5 to 6.5
Lettuce	6.0 to 6.5	Turnips	5.5 to 6.5
Mustard	5.5 to 6.5	Watermelons	5.0 to 5.5
Okra	6.0 to 6.5		

A Useful Chart for Teaching the Relation of Soil Reaction to the Availability of Plant Nutrients to Crops, by N. A. Pettinger, Virginia Agricultural Exp. Sta. Bull. No. 136. Page 18.

COMPOUND INTEREST

Table Showing the Amount of \$1 Compounded Annually at Different Rates.

Years	2%	2½%	3%	3½%	4%	5%	6%
1.....	1.0200	1.0250	1.0300	1.0350	1.0400	1.0500	1.0600
2.....	1.0404	1.0506	1.0609	1.0712	1.0816	1.1025	1.1236
3.....	1.0612	1.0769	1.0927	1.1087	1.1249	1.1576	1.1910
4.....	1.0824	1.1038	1.1255	1.1475	1.1699	1.2155	1.2625
5.....	1.1041	1.1314	1.1593	1.1877	1.2167	1.2763	1.3382
6.....	1.1262	1.1597	1.1941	1.2293	1.2653	1.3401	1.4185
7.....	1.1487	1.1887	1.2299	1.2723	1.3159	1.4071	1.5036
8.....	1.1717	1.2184	1.2668	1.3168	1.3686	1.4775	1.5938
9.....	1.1951	1.2489	1.3048	1.3629	1.4233	1.5513	1.6895
10.....	1.2190	1.2801	1.3439	1.4106	1.4802	1.6289	1.7908
11.....	1.2434	1.3121	1.3842	1.4600	1.5395	1.7103	1.8983
12.....	1.2682	1.3449	1.4258	1.5111	1.6010	1.7959	2.0122
13.....	1.2936	1.3785	1.4685	1.5640	1.6651	1.8856	2.1329
14.....	1.3195	1.4130	1.5126	1.6187	1.7317	1.9799	2.2609
15.....	1.3459	1.4483	1.5580	1.6753	1.8009	2.0789	2.3966
16.....	1.3728	1.4845	1.6047	1.7340	1.8730	2.1829	2.5404
17.....	1.4002	1.5216	1.6528	1.7947	1.9479	2.2920	2.6928
18.....	1.4282	1.5597	1.7024	1.8575	2.0258	2.4066	2.8543
19.....	1.4568	1.5987	1.7535	1.9225	2.1068	2.5270	3.0256
20.....	1.4859	1.6387	1.8061	1.9898	2.1911	2.6533	3.2071
21.....	1.5157	1.6796	1.8603	2.0594	2.2788	2.7860	3.3996
22.....	1.5460	1.7216	1.9161	2.1315	2.3699	2.9253	3.6035
23.....	1.5769	1.7646	1.9736	2.2061	2.4647	3.0715	3.8197
24.....	1.6084	1.8087	2.0328	2.2833	2.5633	3.2251	4.0489
25.....	1.6406	1.8539	2.0938	2.3632	2.6658	3.3864	4.2919

Use of the above table: Follow down in the column headed by the interest rate required to the number of years for which interest is to be computed. This is the total amount on \$1. Multiply by the principal for the total amount. The amount of interest equals the principal subtracted from this amount.

ANSWERS

Part I

Page 2. 3) 684 in. 4) 26,400 ft., 316,800 in. 5) 99 yd., 297 ft., 3564 in. 6) 2240 rd., 36,960 ft. 7) 144 ft. 8) 2682 in.

Page 3. 10) 63 ft., 21 yd. 11) 6 yd., 202 yd. 12) 11 mi., 26 mi. 13) 22 rd. 14) 84 rd. 15) 34 rd., 96 rd. 16) $a > 10$ rd. 7 in., $b > 5$ rd. 6 in., $c > 70$ rd. 2 ft. 1 in., $d > 18$ rd. 4 yd. 1 ft. **Page 4.** 18) $\frac{1}{4}$, $\frac{1}{3}$. 19) $\frac{1}{4}$, $\frac{1}{16}$. 20) $282\frac{2}{3}$ yd. 21) $75\frac{1}{3}$ ft., $27\frac{5}{12}$ ft. 22) $578\frac{1}{3}$ yd., $686\frac{1}{3}$ yd. 1) 60. 2) 93. 3) 66. 4) 220 ft. 5) $121\frac{1}{3}$ yd. 6) 150. 7) 40.

Page 5. 1) $473\frac{1}{4}$ ft. 2) $805\frac{1}{2}$ ft. 3) 180. 4) 640. 5) 21. 6) 33. **Page 6.** 8) 18. 11) 99 ft. 5 in. 12) 55 yd. 2 ft. 10 in. 13) 5 ft. 8 in. 14) 10 yd. 1 ft. 11 in. 15) $99\frac{5}{12}$ ft. 16) $5\frac{2}{3}$ ft.

Page 15. 9) $a > 18^\circ$, $b > 54^\circ$, $c > 90^\circ$, $d > 53^\circ$. **Page 16.** 10) $a > 45^\circ$, $b > 40^\circ$, $c > 50^\circ$, $d > 142^\circ$. 11) 12° . 12) 15.

Page 22. 3) $a > 100^\circ$, $b > 50^\circ$. 4) $a > 60^\circ$, $b > 30^\circ$, $c > 47\frac{1}{2}^\circ$.

Page 24. 1) $84\frac{1}{3}$ yd. 2) $175\frac{1}{2}$ ft. 3) $a > 48$ rd., $b > 316$ yd., $c > 2640$ ft. 4) 206 ft. 5) 76 ft. 6 in. 6) 246 rd. 1 yd. 7) 214 yd.

Page 25. 3) 3456 sq. in., 126 sq. ft. 4) 7488 sq. in., 243 sq. ft. 5) 11,664 sq. in., 484 sq. yd. 6) 15,552 sq. in., 363 sq. yd. 7) 800 sq. rd., 24,200 sq. yd. 8) 2080 sq. rd., 62,920 sq. yd. 9) 3200 Acres, 87,120 sq. ft. **Page 26.** 10) 7680 Acres, 174,240 sq. ft. 11) 16 sq. ft., $1\frac{1}{9}$ sq. yd. 12) 30 sq. ft., $3\frac{1}{3}$ sq. yd. 13) 72 sq. yd., 20 sq. rd. 14) 336 sq. yd., 44 sq. rd. 15) 7 Acres, 7 sq. mi. 16) 13 Acres, 8 sq. mi. 18) $\frac{1}{2}$. 19) $\frac{1}{8}$. 20) $\frac{1}{8}$. 21) $\frac{1}{1280}$. **Page 27.** 22) $a > 320$ Acres, $b > 160$ Acres, $c > 80$ Acres, $d > 480$ Acres. 23) $a > \frac{1}{16}$, $b > \frac{3}{8}$, $c > \frac{5}{8}$, $d > \frac{7}{16}$.

Page 28. 2) 1200 sq. yd. 3) \$1875. 4) \$134,400.

Page 31. 3) 5625 sq. ft., 625 sq. yd. 4) \$3915. 5) 3116 sq. ft. 6) 50 sq. ft. 7) 639 sq. yd. 8) 6000 sq. rd.

Page 32. 2) 138 sq. in. 3) 12 sq. ft. 4) 56 sq. ft. 5) 80 sq. ft.

Page 33. 3) $a > 169$ sq. ft., $b > 6889$ sq. ft., $c > 30\frac{1}{4}$ sq. mi., $d > 39\frac{1}{16}$ sq. ft. 4) 7700 sq. ft. 5) 96. **Page 34.** 7) 432. 8) 89,100. 9) $123\frac{1}{3}$ sq. ft. 10) $68\frac{1}{16}$ sq. ft. 11) 2 gal. 12) \$4.80

Page 39. 3) $a > 360$ ft., $b > 484$ ft., $c > 297.3$ ft., $d > 849.6$ ft., $e > 549.7$ ft.

Page 40. 2) $a > 5929$ sq. rd., $b > 3136$ sq. yd., $c > 453.69$ sq. ft., $d > 1755.61$ sq. ft. 3) $a > 21,316$, $b > 88,209$, $c > 135,424$, $d > 69\frac{4}{9}$, $e > 27\frac{4}{9}$, $f > 231\frac{1}{25}$, $g > 2840.89$, $h > 19209.96$, $i > 158244.84$, $j > 11.6964$, $k > 67.0761$, $l > 704.3716$.

Page 43. a) 32. b) 47. c) 58. d) 72. e) 148. f) 186. g) 305. h) 581. i) 5.2. j) 12.6. k) 4.95. l) 3.04.

Page 44. 1) 1.41. 2) 1.73. 3) 2.45. 4) 2.65. 5) 3.16. 6) 3.32. 7) 3.61. 8) 3.74. 9) 3.87. 10) 5.57. 11) 12.12. 12) 16.09. 13) 9.26. 14) 9.67. 15) 27.43. 16) 3.79. **Page 45.** 17) 255.6 ft. 18) 295.2 ft. 19) 330 ft. 20) 361.5 ft. 21) 390.5 ft. 22) 417.4 ft. 23) 442.7 ft. 24) 466.7 ft. 25) 489.5 ft.

Page 49. 1) $a > 2722$, $b > 680$, $c > 6969$. 2) $a > 14,520$, $b > 9680$, $c > 10,454$. 3) 7110. 4) 16,594. 5) 6534. 6) 12,445. 7) 28,002.

Page 50. 1) 5 oz. 2) $24\frac{3}{4}$ lb. 3) $4\frac{1}{2}$ oz. 4) 3.6 pt. 5) 9 pkg. 6) 125 lb. Alf., 100 lb. Orch. Grass, 50 lb. Ky. Grass, $18\frac{3}{4}$ lb. Wh. Clover. 7) 170 lb. Corn, $63\frac{3}{4}$ lb. Sorg., $318\frac{3}{4}$ lb. Cowp. 8) $54\frac{1}{2}$ lb. 9) 2 oz. 10) $12\frac{1}{4}$ Acres. 11) 3 Acres.

Page 52. 1) $a > 27$, $b > 108$, $c > 69$, $d > 302$, $e > 48$, $f > 75$.

Page 53. 2) 14. 3) 435. 4) 2722.

Page 55. 1) $a > 5588$, $b > 125$, $c > 31$, $d > 87$. **Page 56.** 2) $a > 510$, $b > 26$, $c > 24$, $d > 22$.

Page 58. 1) 13,824 cu. in., 324 cu. ft. 2) 17,280 cu. in., 216 cu. ft. 3) 139,968 cu. in. 4) 326,592 cu. in. 5) 4 cu. ft., 22 cu. yd. 6) 2 cu. ft., 32 cu. yd. 7) $\frac{1}{8}$, $\frac{1}{16}$. 8) $\frac{1}{9}$, $\frac{1}{3}$.

Page 59. 2) $a > 440$ cu. ft., $b > 4000$ cu. ft., $c > 748$ cu. ft., $d > 2090$ cu. ft. 3) $a > 5280$ cu. ft., $b > 3402$ cu. ft., $c > 1260$ cu. ft., $d > 2631\frac{3}{4}$ cu. ft. **Page 60.** 1) $a > 1000$ cu. ft., $b > 1728$ cu. ft., $c > 421\frac{7}{8}$ cu. ft., $d > 592.704$ cu. ft., $e > 813\frac{1}{27}$ cu. ft., $f > 561\frac{3}{4}$ cu. ft.

Page 61. 1) 256 bu. 2) 800 bu. 3) 576 bu. 4) 484 bu. 5) 403.2 bu. 6) 967.68 bu. 7) 595.35 bu. 8) 1039.5 bu. 9) 360 bu. 10) 712.8 bu. 11) \$69.12. 12) 5120 lb. 13) \$367.20.

Page 62. 14) \$1322.46. 15) \$319.87. 1) $13\frac{1}{3}$ Tons, 12 Tons. 2) \$141.17. 3) \$105.17. 4) 4 ft. 5) 608 lb. 6) $427\frac{1}{2}$ lb. 7) $a > 50,820$ cu. ft., $b > 15.88+$ ft. 8) 384 cu. yd. **Page 63.** 9) 180. 10) $52\frac{5}{27}$ cu. yd. 11) $31\frac{7}{27}$ cu. yd.

Page 64. 2) $a > 21.6$ Tons, $b > 64.6$ Tons, $c > 51.4$ Tons. 3) 705.6 bu. 4) 1088.64 bu. 5) 128 bu. 6) 240 bu.

Page 65. 1) 5. 2) 12. 3) 25. 4) $22\frac{1}{2}$. 5) $18\frac{3}{4}$. 6) \$24. 7) \$31.50.

Page 68. 3) $a > 44$ ft., $b > 9.42$ in., $c > 47.1$ ft., $d > 22$ in., $e > 50.24$ ft., $f > 66$ in., $g > 31.4$ in. $h > 220$ ft. 4) 81.64 ft.

Page 69. 5) 44. 6) 35 in. 7) $13\frac{4}{11}$ ft. 8) 3977.3 mi.

Page 70. 3) $a > 113.04$ sq. in., $b > 154$ sq. ft., $c > 1962.5$ sq. ft., $d > 1386$ sq. ft., $e > 616$ sq. ft., $f > 78.5$ sq. in., $g > 19.625$ sq. in., $h > 415.265$ sq. ft. 4) 12.56 sq. in. **Page 71.** 6) 154 sq. in. 7) 7850 sq. ft. 8) 113.04 sq. ft. 9) $a > 94.2$ ft., $b > 706.5$ sq. ft. 10) $38\frac{1}{2}$ sq. ft., 154 sq. ft. 11) 1 to 9.

Page 72. 1) $a > 942$ cu. ft., $b > 2156$ cu. ft., $c > 10^{10}\frac{1}{21}$ cu. ft., $d > 6\frac{2}{3}$ cu. ft., $e > 11,000$ cu. ft., $f > 0.785$ cu. ft., $g > 10,395$ cu. ft., $h > 18086.4$ cu. ft. 2) 445.5 cu. ft., 16.5 cu. yd. 3) 9420 cu. ft. **Page 73.** 4) 44 days. 1) 66,000 lb. 2) 157 days. **Page 74.**

3) 178.2 Tons. 4) 125 days. 5) 7 Acres. 6) 1485 gal. 7) 4710 gal. 8) $12\frac{4}{3}$ bbl. 9) 1108.8 bbl.

Page 75. 1) $513\frac{1}{3}$ cu. ft. 2) 211.2 bu. 3) 209.3 bu.

Page 78. 1) 26.3 Tons. 2) 39.8 Tons. 3) \$258.62. 4) \$370.48.

Page 84. 2) $b > 27.7$ rd. 3) $b > 20$ yd., $c > 1400$ sq. yd.

Page 85. 6) $a > 756$ sq. rd., $b > 816$ sq. rd. 1) $c > 14.4$ Acres. 3) $b >$ Fields A, B, C, D, and E, 60 Acres each; Field F1, 15 Acres; Field F2, $16\frac{7}{8}$ Acres; Field F3, $19\frac{1}{16}$ Acres; Farmstead, $8\frac{7}{16}$ Acres.

Page 91. 1) 308 bd. ft. 2) 165 bd. ft. 3) 75 bd. ft. 4) 196 bd. ft. 5) 340 bd. ft. 6) 84 bd. ft. 7) 105 bd. ft. 8) 210 bd. ft. 9) 252 bd. ft. 10) 32 bd. ft. 11) 48 bd. ft. 12) 80 bd. ft. 13) 112 bd. ft. 14) 108 bd. ft. 15) 160 bd. ft. 16) 112 bd. ft. 17) 240 bd. ft. 18) 56 bd. ft. 19) 280 bd. ft. 20) 48 bd. ft.

Page 92. 1) \$113.85. 2) \$29.52. 3) \$27.65. **Page 93.** 4) \$75.36. 5) \$169.20. 6) \$138.15. 7) \$131.29. 8) \$83.46. 9) \$59.20. 10) \$49.96. 11) $a > 64, 110, 8, 65\frac{1}{3}, 21\frac{1}{3}, 64, 46\frac{2}{3}, 20, 220,$ and 575 bd. ft.; $b > 1194\frac{1}{3}$ bd. ft.; \$38.22. 12) \$7.74, \$5.23, \$0.97, \$13.94 total.

Page 98. 9) 333 bd. ft. 10) 1848 bd. ft. 16) 45.1 bd. ft. 17) 1775 bd. ft. 18) 66.7 bd. ft. 19) 516 bd. ft. 20) 69.3 bd. ft.

Page 105. 1) 10. 2) 24. 3) 2. 4) 40. 5) $8\frac{3}{4}$. 6) $3\frac{3}{11}$. 7) $4\frac{2}{3}$. 8) $9\frac{3}{4}$. 9) $13\frac{3}{5}$. 10) $8\frac{4}{7}$. 11) $19\frac{5}{7}$. 12) $4\frac{1}{14}$. 13) $6\frac{3}{4}$. 14) $12\frac{1}{2}$. 15) 10. 16) 81. 17) $4\frac{1}{5}$. 18) $3\frac{3}{7}$.

Page 111. 1) 104 ft. 2) 62 ft. 3) 92 ft. 4) 29 ft. 5) 42 ft.

Page 112. 6) 156 ft. 7) 65 ft.

Page 114. 1) 42 ft. 2) 28 ft. 3) 44 ft.

Page 120. 1) $a > 170$ rd., $b > 60$ rd. 2) 25 ft. 3) 36.4 ft.

Page 121. 4) 4.2 ft. 5) 20.9 ft. 6) 36 rd. 7) 18 rd. 8) $a > 5.7$ ft., $b > 22.8$ sq. ft. 9) 17.3 ft.

Page 122. 1) 14.4 ft. 2) 14.1 ft. 3) 19.0 ft. 4) 14.4 ft. 5) 16.8 ft.

Page 125. 41) $7\frac{1}{13}\%$. 42) $41\frac{1}{21}\%$. 43) $51\frac{1}{17}\%$. 44) $5\frac{5}{9}\%$. 45) $1\frac{2}{3}\%$. 46) $1\frac{3}{4}\%$. 47) $1\frac{1}{4}\%$. 48) $2\frac{2}{9}\%$. 49) 55%. 50) 65%. 51) 75%. 52) 85%. 53) $31\frac{1}{4}\%$. 54) $43\frac{3}{4}\%$. 55) $41\frac{2}{3}\%$. 56) $58\frac{1}{3}\%$.

Page 127. 1) 10.64 lb. 2) 159.36 gal. 3) 4.98 bu. 4) 40.11 lb. 5) 2.774 qt. 6) 13.6675 lb. 7) \$12. 8) \$12.50. 9) \$61.40. 10) \$12.03. 11) 45 Tons. 12) 110 lb. 13) 19.376 bu. 14) 21.978 Tons. 15) 0.483 qt. 16) 0.1748 lb. 17) 0.064 qt. 18) 0.081 lb.

Page 128. 2) 18%. 3) 35%. 4) 7.5%. 5) $22\frac{2}{9}\%$. 6) $68\frac{3}{4}\%$. 7) $28\frac{1}{4}\%$. 8) $88\frac{8}{9}\%$. 10) 37.9%. 11) 5.2%. 12) 15.7%. 13) 7.4%. 14) 11.4%. 15) 17.1%.

Page 129. 2) 55 qt. 3) 80 Acres. 4) 125 lb. 5) 64 bu. **Page 130.** 7) 207 Tons. 8) 181 Acres. 9) 8135 lb. 10) 8244 qt. 1) \$176.54. 2) \$7125. 3) \$178.10. 4) \$16. 5) \$14.40. 6) $66\frac{2}{3}\%$. 7) 39.1%. 8) 860 lb. 9) \$10,000. 10) $12\frac{1}{2}\%$. 11) 2076.9 lb.

Part II

Page 133. 2) 118.25 lb. 3) 352.6 lb. 4) 1535.1 lb. 5) 1251.3 lb. **Page 134.** 6) 1771.6 lb. 7) 198.875 lb. 8) 78.475 lb. 9) 1263.125 lb. 10) 777.225 lb. 11) 1577.025 lb. 13) 21.4 qt. 14) 38.6 qt. 15) 21.5 qt. 16) 43.5 qt. 17) 16.1 qt. 18) 346.0 qt. 19) 397.2 qt. 20) 355.4 qt. 21) 833.7 qt. 22) 1101.9 qt. 23) $a > 105.8$ lb., $b > 49.2$ qt. 24) $a > 89.1$ lb., $b > 41.4$ qt. 25) 85.4 lb., 39.7 qt. **Page 135.** 26) 3710.2 qt. 1) 740.35 lb. Water, 33.15 lb. MF., 21.25 lb. Cas., 5.95 lb. Alb., 43.35 lb. MS., 5.95 lb. Ash. 2) 563.2 lb. Water, 22.4 lb. MF., 17.28 lb. Cas., 3.2 lb. Alb., 29.44 lb. MS., 4.48 lb. Ash. 3) 191.1 lb. Water, 140 lb. MF., 18.9 lb. MSNF. **Page 136.** 4) 355.2 lb. Water, 88.8 lb. MF., 36 lb. MSNF.

5) 23.25 lb. Water, 121.5 lb. MF., 4.2 lb. Salt, 1.05 lb. Cas. 6) 24.325 lb. Water, 144.2 lb. MF., 6.475 lb. SNF.

Page 138. 1) 31.08 lb. 2) 3.85 lb. 3) 138.7 lb. 4) 173.46 lb. 5) 3.4 lb. 6) 2.24 lb. 7) 0.216 lb. 8) 0.556 lb. 9) 4.2%. 10) 3.7%. 11) 21%. 12) 34%. **Page 139.** 13) 365 lb. 14) 840 lb. 15) 675 lb. 16) 1227 lb. 17) 1213 lb. **Page 140.** 18) 4.1%. 19) 41,500 lb. 20) 50 lb., 18,250 lb.

Page 141. 1) 3.4%. 2) 3.8%. 3) 3.8%.

Page 142. 2) 210 lb. 3) 250 gal., 950 gal.

Page 143. 5) 1450 lb. 6) 820 gal. 7) 500 lb., 440 lb.

Page 144. 2) 20%, \$22.40. 3) 20%, \$28.35. 4) 15%, 459 lb. 6) 433.2 lb., 516.8 lb. 7) 491.4 lb., 708.6 lb.

Page 145. 1) a > \$18.88, b > \$14.56, c > \$23.76, d > \$15.12, e > \$13.80, f > \$19.38, g > \$23.18, h > \$15.30, i > \$18.20, j > \$18.55. 2) a > 360 lb., 350 lb.; b > 10 lb.; c > \$2.80; d > 6600 lb.; e > 0.15%. 3) a > 1200 lb., b > 4800 lb., c > 600 lb., d > 5400 lb., e > 600 lb., \$3.

Page 146. 4) a > \$22.50, b > \$26.60, c > \$19.76. 5) a > 544.17 lb., b > 653 lb., c > \$202.43. 6) 285 lb. Water, 225 lb. MF., 240 lb. MSNF. 7) 66.24 lb. 8) 141.15 lb. 9) 126.72 lb. 10) 225.18 lb.

Page 151. 2) 720 lb. of 39%, 120 lb. of 18%. **Page 152.** 3) 336 gal. of 37%, 294 gal. of 22%. 4) 660 lb. of 19%, 220 lb. of 35%. 5) 490 lb. of 29%, 385 lb. of 4%. 6) 480 qt. of 3%, 680 qt. of 32%. 7) 1020 lb. of 30.3%, 315 lb. of 3.6%. 8) 420 qt. of 4.1%, 1045 qt. of 33.4%. 9) 1610 lb. of 26%, 600 lb. of 3.9%. 10) 235.3 gal. of 21%, 264.7 gal. of 38%. 11) 338.5 lb. of 3%, 461.5 lb. of 29%. 12) 213.3 qt. of 32.7%, 386.7 qt. of 19.2%. 13) 432.5 lb. of 28.4%, 267.5 lb. of 3.8%.

Page 153. 14) a > 150 lb., 330 lb.; b > 6 Jerseys, 10 Holsteins. 15) Holsteins, 750 lb., 15 cows; Brown Swiss, 450 lb., 15 cows. 16) Holsteins, 440 lb., 10 cows; Guernseys, 240 lb., 8 cows.

Page 154. 1) 38 lb. 2) 180 lb. 3) 60 gal. 4) 420 qt. 5) a > 440 lb., b > 120 lb., c > 4 cows. **Page 155.** 6) a > 960 lb., b > 320 lb., c > 16 cows, d > 1280 lb.

Page 157. 1) 28.68 lb. Water, 0.92 lb. Prot., 0.36 lb. Fat, 2.76 lb. Fib., 6.6 lb. N-Free Ex., 0.68 lb. Ash. 2) 130 lb. Water, 864 lb. Prot., 144 lb. Fat, 212 lb. Fib., 540 lb. N-Free Ex., 110 lb. Ash. 3) C.S., 23.4%; C.M., 37.6%; Oats, 71.2%; P.G., 18.2%; T.H., 75.1%; W.B., 63.8%. **Page 158.** 4) a > 5.442 lb., b > 9.977 lb., c > 14.512 lb., d > 3.628 lb. 5) a > 10.644 lb., b > 14.192 lb., c >

17.74 lb., d > 12.418 lb. 6) C.S., 358.5 lb.; C.M., 32.5 lb.; Oats, 46.5 lb.; P.G., 364.5 lb.; T.H., 56.5 lb.; W.B., 47 lb. 7) a > 23.5 lb., b > 15 lb., c > 211.5 lb.

Page 158. 1) 9.0 lb. Prot., 1.0 lb. Fat, 1.6 lb. Fib., 57.0 lb. N-Free Ex. **Page 159.** 2) 1.4 lb. Prot., 0.3 lb. Fat, 2.8 lb. Fib., 5.5 lb. N-Free Ex.

Page 161. 3) a > 9 lb., b > 15.75 lb., c > 1.8 lb., d > 0.495 lb., e > 135 lb., f > 162 lb., g > 130.5 lb., h > 69.75 lb. 4) a > 44.2 lb., b > 83.7 lb., c > 20.7 lb., d > 71.3 lb. 5) a > 9.4 lb., b > 5.1 lb., c > 1404.5 lb., d > 989 lb. 6) Bar., 78.6 lb.; Buck., 64.5 lb. 7) Soy. Hay, 9.1 lb.; Mix. Gr. Hay, 8.3 lb. 8) R. Cl. Hay, 739.2 lb.; Al. Hay, 882 lb. 9) a > Oats, 514.8 lb.; b > Rye, 544.7 lb. **Page 162.** 10) a > 10.9 lb., b > 38.1 lb., c > 50.6 lb., d > 74.4 lb. 2) \$1.92. 3) \$1.81. **Page 163.** 4) \$2.05. 5) \$1.92. 6) \$1.72. 7) \$1.23. 8) \$2.10.

Page 164. 2) 9.2 cents. 3) 10.3 cents. 4) 6.1 cents. 5) a > S.O.M., \$1.96; D.D.G., \$1.97; b > S.O.M., 4.8 cents; D.D.G., 7.4¢; c > S.O.M. 6) a > Bar., \$1.92; Corn, \$2.21; b > Bar., 16.2 cents; Corn, 16.5 cents; c > Barley.

Page 167. 2) a > 1 : 6.4, b > 1 : 48.0, c > 1 : 4.4, d > 1 : 4.4, e > 1 : 2.9, f > 1 : 15.2, g > 1 : 1.5, h > 1 : 10.4, i > 1 : 9.4, j > 1 : 3.2. **Page 168.** 4) 1 : 8.9. 5) a > 1 : 1.3, b > 1 : 8.4, c > 1 : 42.8, d > 1 : 6.0, e > 1 : 1.8.

Page 169. 1) 1 : 6.9, D.P. 2.39 lb., T.D.N. 18.85 lb. **Page 170.** 2) 1 : 7.8, D.P. 1.47 lb., T.D.N. 12.99 lb.

3) $\begin{cases} 1:3.8 \\ \text{D.P. 2.68 lb.} \\ \text{D.C. 8.66} \\ \text{D.F. 0.68} \end{cases}$ **Page 4)** $\begin{cases} 1:4.1 \\ \text{D.P. 2.43 lb.} \\ \text{D.C. 8.34} \\ \text{D.F. 0.70} \end{cases}$ a > $\begin{cases} 1:4.1 \\ \text{D.P. 2.43 lb.} \\ \text{D.C. 8.37} \\ \text{D.F. 0.70} \end{cases}$ b > $\begin{cases} 1:2.8 \\ \text{D.P. 0.52 lb.} \\ \text{D.C. 1.18} \\ \text{D.F. 0.12} \end{cases}$ 5)

Page 172. 1) a > Total D.M., 2.67 lb.; Total Dig. Prot., 0.30 lb.; T.D.N., 2.03 lb.; b > 1 : 5.8. **Page 173.** 2) a > Ration A: Total D.M., 24.14 lb.; Total Dig. Prot., 2.03 lb.; Total Dig. Carb., 15.62 lb.; Total Dig. Fat, 0.81 lb. Ration B: Total D.M., 19.74 lb.; Total Dig. Prot., 1.34 lb.; Total Dig. Carb., 11.55 lb.; Total Dig. Fat, 0.51 lb.; b > Ration A: T.D.N., 19.47 lb.; Ration B: T.D.N., 14.04 lb.; c > Ration A: 1 : 8.6; Ration B: 1 : 9.5; d > Ration A.

Page 175. 1) 18.6%. 2) 16.0%. **Page 176.** 3) a > 13.4%, b > 10.4%.

Page 177. 2) 27 lb. Silage, 11¼ lb. hay, 6.6 lb. grain. 3) 39 lb. silage, 16¼ lb. hay, 5 lb. grain. 4) 36 lb. silage, 15 lb. hay, 4.95 lb.

grain. 5) 33 lb. silage, $13\frac{3}{4}$ lb. hay, 6 lb. grain. 6) 24 lb. silage, 10 lb. hay, 5.4 lb. grain. 7) 42 lb. silage, $17\frac{1}{2}$ lb. hay, 7 lb. grain.

Page 179. 1) Dig. Prot., 1.093 lb.; Therms, 10.5854. 2) Dig. Prot., 1.455 lb.; Therms, 13.634. 3) Dig. Prot., 2.045 lb.; Therms, 17.2422. **Page 180.** 4) a> Dig. Prot., 0.601; Therms, 7.60; b> Dig. Prot., 0.488; Therms, 6.6682.

Page 184. 1) a> 234,000 lb., b> 340,000 lb., c> 408,000 lb., d> 540,000 lb. **Page 185.** 2) a> 37,800 lb., b> 48,200 lb. 3) a> 2860 lb., b> 3870 lb., c> 5544 lb. **Page 186.** 4) a> 1040 lb., b> 2150 lb., c> 770 lb. 5) a> 15,860 lb., b> 36,335 lb., c> 44,968 lb. 1) a> 2142 lb. N, 619.5 lb. P, 8232 lb. Ca.; b> 2793 lb. N, 516.6 lb. P, 8114.4 lb. Ca.; c> 38.16 lb., d> Rot., 4284.2 lb.; Grass, 4619 lb.; e> 1428 lb. **Page 187.** 2) \$362.70. 3) \$149.50. 4) b> 6.745 Tons, c> 8.06 Tons, d> 5.805 Tons.

Page 190. 1) 49.5 lb. N, 8 lb. P, 68 lb. K, 13.5 lb. Ca. 2) 40.48 lb. N, 7.36 lb. P, 68.08 lb. K, 11.04 lb. Ca. 3) 33.6 lb. N, 4.8 lb. P, 43.2 lb. K, 0.96 lb. Ca. 4) 123.2 lb. N. 5) 15.96 lb. P, 153.52 lb. K, 108.68 lb. Ca. 6) 9.36 lb. P, 82.16 lb. K, 62.92 lb. Ca. 7) 11 lb. P, 36.08 lb. K, 42.24 lb. Ca. 8) 52.3776 lb. N, 9.6024 lb. P, 56.712 lb. K, 12.3552 lb. Ca. 9) 40.2032 lb. N, 8.0272 lb. P, 28.5024 lb. K, 7.3024 lb. Ca. 10) 50.3 lb. N, 5.01 lb. P, 40.03 lb. K, 0.36 lb. Ca. 11) 80.04 lb. N, 11.624 lb. P, 65.824 lb. K, 15.028 lb. Ca. 12) 8.4 lb. N, 135 lb. P, 2.1 lb. K, 1.8 lb. Ca. 13) 8.85 lb. N, 1.8 lb. P, 2.1 lb. K, 2.1 lb. Ca. 14) 9.984 lb. N, 2.496 lb. P, 22.464 lb. K, 2.496 lb. Ca. 15) 243 lb. N, 1.35 lb. P, 207 lb. K, 0.45 lb. Ca.

Page 192. 1) 7.5 lb. N, 0.78 lb. P, 0.75 lb. K. 2) 9.55 lb. N, 1.29 lb. P, 1.68 lb. K. 3) 25 lb. N, 2.88 lb. P, 9.96 lb. K. 4) 23.2 lb. N, 2.37 lb. P, 2.76 lb. K. 5) 14.7 lb. N, 1.65 lb. P, 2.1 lb. K. 6) Losses: 3.93 lb. P, 31.44 lb. K; Gain: 73.5 lb. N. 7) Losses: 2.61 lb. P, 19.92 lb. K; Gain: 42 lb. N. 8) Losses: 3.66 lb. P, 10.98 lb. K; Gain: 46 lb. N. 9) 23.2 lb. N, 5.53 lb. P, 6.44 lb. K. 10) 250 lb. N, 67.2 lb. P, 232.4 lb. K. 11) 168 lb. N, 24.36 lb. P, 185.92 lb. K.

Page 193. 1) a> 588 lb., b> 294 lb., c> 690 lb., d> 2492 lb., e> 305 lb., f> 1712 lb. 2) 156.8 lb. 3) 15.4 lb. loss. 4) 93.1 lb. gain. 5) a> 15 lb. gain, b> 11.8 lb. P, 58.8 lb. K. 6) a> 36.9 lb. loss, b> 32.8 lb. P, 103.7 lb. K.

Page 196. 1) 8.9425 Tons. 2) 13.6875 Tons. 3) 7.3 Tons.

Page 197. 4) 7.3 Tons. 5) 4.1975 Tons. 6) 50 Tons. 7) 1080 Tons. 8) 64,000 lb., 4 Acres.

Page 198. 1) \$2.95, \$2.42, \$2.95, \$5.56, \$2.06, \$3.70. **Page 199.** 2) 3 lb., 3.6 lb., 5.2 lb., 1.8 lb. 3) \$2.06. 4) 80 lb. N, 16 lb. P, 64 lb. K. 5) 1180 lb., 1580 lb., 1560 lb., 1280 lb., 1740 lb., 1100 lb.

Page 200. 1) 20 lb. 2) 47 lb. 3) 39 lb. 4) $a > 360$ lb., $b > 960$ lb. **Page 201.** 5) 14%. 6) 45%. 7) 155 lb. 8) 432 lb. 9) 355 lb. 10) 6 cents. 11) 9 cents.

Page 202. 2) 10 lb. N, 20 lb. P_2O_5 , 10 lb. K_2O . 3) 12.75 lb. N, 51 lb. P_2O_5 , 63.75 lb. K_2O . 4) 14 lb. N, 42 lb. P_2O_5 , 14 lb. K_2O . 5) \$14.80. 6) \$45.20. 7) $a > \$28$, $b > \$8.70$. **Page 203.** 8) $a > \$36$, $b > \$8.80$. 10) $a > 7$ lb. N, 24.472 lb. P, 5.81 lb. K; $b > 18$ lb. N, 31.464 lb. P, 29.88 lb. K; $c > 5.244$ lb. P, 39.84 lb. K; $d > 27.5$ lb. N, 7.2105 lb. P, 9.13 lb. K; $e > 26.0015$ lb. P, 21.165 lb. K; $f > 28$ lb. N, 15.295 lb. P.

Page 204. 2) \$11.10. 3) \$32.20.

Page 205. 4) $a > \$24.40$, $b > \$48.80$, 24; $c > \$36$, 24. 5) $a > 40$, \$1.35; $b > 40$, \$1.60.

Page 206. 1) $a > 0.75$ units, 15 lb.; $b > 75$ lb. 2) $a > 80$ lb., $b > 500$ lb.

Page 207. 1) $a > 40$ lb. N, 240 lb. P, 40 lb. K.; $b > 200$ lb. Am. Sul., 1500 lb. Super., 300 lb. Kainit; $c > \$21.95$ per ton. 2) 200 lb. of N. of S., 139 lb. of C.M., 1000 lb. Super., 320 lb. M.P., 341 lb. filler.

Page 209. 1) \$3.33. 2) \$34.40. 3) $a > 1480$ lb., $b > 5250$ lb., $c > 450$ lb., $d > 2016$ lb., $e > 3150$ lb.

Page 214. 1) 200 lb. 2) 72 lb. 3) 10 lb. 4) $67\frac{1}{2}$ lb. 5) $56\frac{1}{4}$ lb. **Page 215.** 6) 1280 lb.

Page 216. 1) 1400 lb. horse at 30 in., 1600 lb. horse at 26 in. 2) 1200 lb. horse at 29 in., 1600 lb. horse at 22 in. 3) 1300 lb. horse at 26 in., 1500 lb. horse at 22 in. 4) 1200 lb. horse at 29 in., 1500 lb. horse at 23 in.

Page 217. 1) 150 lb., 200 lb., 250 lb., 300 lb. 2) 400 lb., 500 lb., 600 lb., 900 lb.

Page 219. 2) 138 R.P.M. 3) 28 Teeth. 5) 12 in. 6) 78 R.P.M. 7) 60 Teeth. **Page 220.** 8) 330 R.P.M. 9) 82 R.P.M. 10) 10 in. 11) 120 R.P.M.

Page 221. 1) 185,625 ft. lb. 2) 178,200 ft. lb. 3) 1,161,600 ft. lb. 4) 1,056,000 ft. lb. 5) $a > 18,000$ ft. lb., $b > 18,000$ ft. lb., $c > \text{Input} = \text{Output}$. 6) $a > 75,000$ ft. lb., $b > 75,000$ ft. lb., $c > 75,000$ ft. lb.

Page 222. 1) 1.1 H.P. **Page 223.** 2) 1.0 H.P. 3) 0.8 H.P. 4) 0.8 H.P. 5) 1.0 H.P. 6) 5.9 H.P. 7) 6.4 H.P. 9) 3,465,000 ft. lb. 10) $a > 8,712,000$ ft. lb., $b > 1.1$ H.P.

Page 225. 2) 4.9 H.P. 3) 2.7 H.P. 4) 3.5 H.P. 5) 4.9 H.P. 6) 5.3 H.P.

Page 226. 1) \$2.40. 2) 7 cents. 3) \$1.09. 4) \$1.37. 5) $a > \$0.94$, $b > \$1.18$, $c > \$1.72$, $d > \$2.30$, $e > \$2.60$, $f > \$3.00$, $g > \$3.60$, $h > \$4.12$, $i > \$4.44$, $j > \$5.20$, $k > \$5.82$, $l > \$6.03$.

Page 229. 1) 5 cu. ft. sand, 7 cu. ft. gravel. 2) 9 pails sand, 18 pails gravel. **Page 230.** 3) 1 cu. ft. sand, 2 cu. ft. gravel. 4) 1 cu. yd. sand, 2 cu. yd. gravel. 5) 1 : 2 : 2. 6) 1 : 2.5 : 4. 7) 1 : 2.5 : 5.

Page 231. 1) $a > 24$ gal., $b > 54$ gal. 2) $a > 30$ gal., $b > 55$ gal. 3) $a > 35$ gal., $b > 50$ gal. 4) $a > 35$ gal., $b > 56$ gal.

Page 233. 1) 84 sacks cem., 3.11 cu. yd. sand, 5.29 cu. yd. grav. 2) 42 s.c., 3.15 c.y.s. 3) 41.88 s.c., 3.48 c.y.s., 4.69 c.y.g. 4) 47.7 s.c., 5.3 c.y.s. 5) $16\frac{1}{4}$ s.c., 1.69 c.y.s., 2.41 c.y.g. 6) $41\frac{1}{2}$ s.c., 3.47 c.y.s., 4.67 c.y.g. 7) $83\frac{1}{2}$ s.c., 3.08 c.y.s., 5.25 c.y.g. 8) 62 s.c., 4.03 c.y.s., 4.57 c.y.g. **Page 234.** 10) $58\frac{1}{2}$ s.c., 6.07 c.y.s., 8.63 c.y.g. 11) 46.31 s.c., 3.85 c.y.s., 5.19 c.y.g. 12) 231.5 s.c., 19.26 c.y.s., 25.93 c.y.g. 13) $46\frac{2}{3}$ s.c., 1.73 c.y.s., 2.94 c.y.g. 15) 30.95 s.c., 3.22 c.y.s., 4.58 c.y.g. **Page 235.** 16) 108.75 s.c., 11.31 c.y.s., 16.10 c.y.g. 17) 19.0 s.c., 1.58 c.y.s., 2.13 c.y.g. 18) 9.06 s.c., 0.75 c.y.s., 1.02 c.y.g. 19) 17.7 s.c., 1.84 c.y.s., 2.62 c.y.g.

Page 236. 21) 221.5 s.c., 18.43 c.y.s., 24.81 c.y.g. 22) 106.94 s.c., 8.90 c.y.s., 11.98 c.y.g. 23) 41.44 s.c., 3.45 c.y.s., 4.64 c.y.g.

Page 237. 24) 98.38 s.c., 8.18 c.y.s., 11.02 c.y.g.

Page 238. 1) \$90. 2) \$216. 3) \$110. 4) \$349. 5) \$11.70. 6) \$28.80. **Page 239.** 7) \$88.75. 8) \$106.25. 9) \$218.50. 10) \$252. 11) \$39.90. 12) \$64.84. 13) \$40.98. 14) \$478.50. 15) \$783.75. 16) \$1445.50. 17) \$1318.75. 18) \$766. 19) \$708.75. 20) \$595.31.

Page 240. 1) \$265. 2) \$143.50. 3) \$104.50. 4) \$81.25. 5) \$194.75. 6) \$6.17. 7) \$18.50. 8) \$21.50. 9) \$58.33. 10) \$1.11. 11) \$3.23. 12) \$12.10. 13) \$11.72. 14) \$5.85. 15) \$11.35.

Page 241. 1) \$69.06. 2) \$103.50. 3) \$50.63. **Page 242.** 5) \$300, \$296.88. 6) \$360, \$357. 7) \$261.88, \$259.13, \$256.38, \$253.63. 8) \$428.75, \$424.81, \$420.88, \$416.94.

Page 243. 1) 25%. 2) 30%. 3) 50%. 4) 24%.

Page 244. 2) $a > 22.9\%$, $b > 33\frac{1}{2}\%$, $c > 27.3\%$,
 $d > 30.8\%$.

Page 245. 4) 9.2% . 5) 8.3% . 6) 9.1% . 7) 10.7% .

Page 248. 1) \$405.85. 2) \$971.80. 3) \$9938.93. 4) \$9992.18.
 5) \$108. 6) \$396.

Page 251. 1) \$4134.11. 2) \$1657.16. 3) \$1130.19, \$200.19.

Page 252. 4) \$979.05, \$220.95 loss.

Page 253. 1) \$7828. 2) \$1744. 3) \$820. 4) 7.7% . 5) 8.0% .
 6) 3.1% .

Page 254. 1) $a > \$71.61$, $b > \$39$, $c > 46$ cents, 71 cents, 25 cents.
 2) $a > \$122.44$, $b > \$28.18$, $c > 50$ cents, 62 cents, 12 cents.
 3) $a > \$39.98$, \$46.22, \$6.24; $b > \$4.86$. 4) $a > \$11.42$, \$14.87;
 $b > \$3.45$.

Page 255. 5) \$2.56. 6) \$1.14, \$0.25. 7) $a > 150$, $b > 597$,
 $c > 7477$. 8) \$21.40.

Page 256. 9) 58 cents. 10) 13 cents.

Page 260. 2) $b > 1932$, \$5.00; 1933, \$8.33; 1934, \$10.26; 1935,
 \$10.15; 1936, \$12.76.

Page 262. 2) $a > 12.4$ lb. 4) $a > 19.5$ bu., $b > 20.8$ in.

Arithmetic Drills

Drill No. 1. 1) $13\frac{3}{4}$. 2) $20\frac{7}{8}$. 3) $38\frac{11}{12}$. 4) $21\frac{17}{24}$. 5)
 $63\frac{1}{4}$. 6) $42\frac{1}{8}$. 7) $83\frac{1}{12}$. 8) $75\frac{1}{24}$. 9) $101\frac{3}{20}$. 10) $100\frac{7}{24}$.

Drill No. 2. 1) $13\frac{1}{4}$. 2) $5\frac{3}{8}$. 3) $8\frac{5}{12}$. 4) $21\frac{3}{10}$. 5) $25\frac{5}{24}$.
 6) $13\frac{5}{8}$. 7) $14\frac{5}{8}$. 8) $22\frac{11}{12}$. 9) $14\frac{31}{40}$. 10) $14\frac{1}{24}$.

Drill No. 3. 1) 132. 2) $82\frac{1}{2}$. 3) 40. 4) $38\frac{1}{2}$. 5) 96. 6)
 231. 7) 60. 8) $133\frac{1}{3}$. 9) $121\frac{1}{2}$. 10) $68\frac{1}{4}$.

Drill No. 4. 1) 99. 2) 128. 3) $9\frac{1}{8}$. 4) $3\frac{3}{4}$. 5) 14. 6) $4\frac{5}{16}$.
 7) $83\frac{1}{3}$. 8) $2\frac{1}{20}$. 9) $43\frac{3}{4}$. 10) $12\frac{3}{16}$.

Drill No. 5. 1) $\frac{5}{16}$. 2) $\frac{1}{2}$. 3) $3\frac{1}{2}$. 4) 2. 5) 50. 6) $36\frac{5}{8}$.
 7) $38\frac{3}{4}$. 8) $81\frac{2}{3}$. 9) $38\frac{13}{16}$. 10) $256\frac{2}{3}$.

Drill No. 6. 1) 110. 2) 12. 3) $346\frac{1}{2}$. 4) 20. 5) 100. 6)
 392. 7) $250\frac{1}{4}$. 8) $140\frac{1}{4}$. 9) 4950. 10) 7700.

Drill No. 7. 1) $\frac{3}{16}$. 2) $1\frac{9}{21}$. 3) 12. 4) $1\frac{1}{3}$. 5) $7\frac{3}{11}$. 6)
 $2\frac{3}{41}$. 7) $\frac{3}{4}$. 8) $\frac{9}{22}$. 9) $\frac{5}{6}$. 10) $2\frac{1}{27}$.

Drill No. 8. 1) 1.008. 2) 43.07. 3) 92.16. 4) 1.9448. 5)
 247.22. 6) 0.0529. 7) 5.6115. 8) 11.9716. 9) 0.01022. 10)
 0.002988.

ANSWERS

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Drill No. 9. 1) 3.8. 2) 0.83. 3) 9.6. 4) 0.58. 5) 15.4. 6) 0.074. 7) 2.71. 8) 0.096. 9) 56. 10) 730.

Drill No. 10. 1) 1.3. 2) 3.8. 3) 12.5. 4) 9.5. 5) 0.4. 6) 1.9. 7) 5.2. 8) 0.9. 9) 55.4. 10) 85.4.

Drill No. 11. 1) 26. 2) 4370. 3) 6820. 4) 1890. 5) 124,600. 6) 1640. 7) 278.4. 8) 10,350. 9) 262,800. 10) 5120. 11) 2895. 12) 25,860.

Drill No. 12. 1) 85. 2) 0.934. 3) 0.0367. 4) 0.91. 5) 3.25. 6) 0.231. 7) 0.19. 8) 1.58. 9) 0.024. 10) 1.67. 11) 0.145. 12) 0.0942.

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